Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 234 SEPTEMBER, 1942 No. 3

BENJAMIN FRANKLIN—ADVENTURES IN AGRICULTURE.* †

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Although Benjamin Franklin was essentially a big-town man, city-born and city-bred, and although his tastes were urban rather than rural, the manifold activities of his amazingly varied career frequently led him into the field of agriculture. This was but natural in a land which was still predominantly rural; it was inevitable for one of such universal interests and boundless talents.

In dealing with Benjamin Franklin's adventures in agriculture we must think of him in two separate roles: first "Franklin the Farmer"; and second, "Franklin the Agricultural Leader." The latter term, I admit, is commonplace, but I have not succeeded in finding a better one. I started out with "Franklin the agricultural scientist," but he was more than this. "Franklin the agricultural philosopher"

* Delivered in the Hall of The Franklin Institute, March 15, 1940. This was one of the papers in the "Meet Dr. Franklin" Conferences.

† Subsequent to the presentation of this lecture at The Franklin Institute on March 15, 1940, additional facts about Benjamin Franklin's ownership of farm lands, at the time unknown, have been disclosed. To bring the story up to date, the author has incorporated the newly discovered data and has revised the text accordingly. Dr. Woodward is now President of Rhode Island State College.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

seemed better, but not altogether satisfactory, suggesting, as it does, the scientist and the thinker. He was more than this; he was above all a man of action, who translated philosophy into works. Presently we shall see how substantially his leadership contributed to agricultural progress. There is much to be said about this phase of his career—more than we can treat exhaustively in the time at our disposal.

I. FRANKLIN THE FARMER.

The record of Franklin the Farmer has long been shrouded in mystery. Biographers and students of Franklin have been puzzled by the absence of specific evidence and by seemingly conflicting data dealing with his practical farm operations. The mystery was projected just one-hundred years ago, when Dr. Jared Sparks issued his 10-volume edition of "The Works of Benjamin Franklin." [1] Here for the first time was published a collection of letters from Franklin to Jared Eliot, clergyman-physician of Guilford, Connecticut, Yale graduate and trustee, who had experimented with agriculture on the side, and whose "Essays on Field Husbandry in New England" constituted the first major American work on agriculture. Included with the letters, which are now in the Sterling Library at Yale, was one bearing no date, in which the author informed Mr. Eliot, "I have perused your two Essays on Field Husbandry, and think the Publick may be much benefited by them; But if the Farmers in your neighbourhood are as unwilling to leave the beaten path of their Ancestors as they are near me, it will be difficult to persuade them to attempt any improvement. . . . About 18 months ago I made a Purchase of about three hundred Acres of Land near Burlington, and resolved to Improve it in the best and Speediest Manner, that I might be Enabled to Indulge my Self in that kind of life which was most agreeable." [2] Then the author proceeded to describe the place, and give a detailed account of his farm operations. There was about eighty acres of deep meadow land. The soil was very fine and black, three feet deep, then it came to "a fatt bluish clay." He scoured out the ditches, plowed it,

[1] Boston, 1840.

[2] Smyth, Albert Henry, "The Life and Writings of Benjamin Franklin," New York, 1905–07, v. 2, p. 383.

sowed oats, mowed them, plowed again, and seeded with red clover and herd grass. He made a minute examination of the clover as it sprouted and grew. On the upland he had a 12-acre depression which formed a round pond because there was no outlet. He drained the pond and found black soil about a foot deep, underlain with a light-colored sandy subsoil. This he seeded to grass and rye.

Ever since this letter was published, it has been accepted tradition that Franklin operated an experimental farm in New Jersey. The letter suggests a desire to retire to a rural life, and although it is undated, the time of the purchase of the farm seems to have been near the time Franklin turned the operation of the printshop over to his partner David Hall. But curiously enough, in his "Autobiography," he made no mention of the farm and gave no indication that he removed his residence from Philadelphia to Burlington for such a period as would be required for the farm operations described. In other letters, he frequently discussed agricultural matters but gave not the slightest hint that he had a farm in New Jersey. Hence upon this letter alone was based the story of the Burlington farm. The letter has been included in all later collections of Franklin's works, e.g., John Bigelow's "The Complete Works of Benjamin Franklin" (10 vols., New York, 1887–89) and Albert Henry Smyth's "The Life and Writings of Benjamin Franklin" (10 vols., New York, 1905–07). And it has been accepted freely and without reservation by Franklin's numerous biographers.

The Quest of the Farm.

From time to time it has been asked, "Where was the farm located?" and "What became of it?" For many years, it was thought to have been the same as Governor William Franklin's estate near Burlington on the Rancocas Creek, commonly known as Franklin Park. It seemed plausible that Benjamin should have conveyed the place to his son for a country seat when the latter became Governor of New Jersey, especially since he could have no personal use for it while he was on his official missions in London. Subsequent events indicate that Benjamin must have been familiar with this place. In 1769, the Governor wrote his father, that he had "entered far into

the spirit of farming," [3] and asked the elder Franklin to send him a drain plow, and a patent plow from England. Then came the Revolution which interrupted William Franklin's career as a country gentleman and the farm was left without a master. But in 1785, when Benjamin was returning from France accompanied by his grandson William Temple Franklin, he visited the exiled William in England. During that historic reconciliation, papers were drawn conveying the Rancocas farm to William Temple, and upon reaching home the grandson took possession. To infer that this was Benjamin's New Jersey farm was, after all, a natural conclusion.

An examination of the recorded deeds in the State House at Trenton, however, revealed that the estate comprised approximately six hundred (not three hundred) acres, that William had purchased it in three separate tracts, and that Benjamin had never owned any portion of it. So it was necessary to seek elsewhere for an answer.

Then began a determined hunt, in which a number of Franklin followers collaborated. Mr. George DeCou of Moorestown, N. J., Mr. William Mason of Evanston, Ill., Mr. George Simpson Eddy of New York City, and Mr. Franklin Bache, of West Chester, Pa., were especially active. No deed or record of transfer or of ownership was to be found in the State archives at Trenton, at the County record office in Mt. Holly, or at the West Jersey Proprietors' office in Burlington. It was suggested that the farm may have been across the river in Pennsylvania, and still be "near Burlington," but a search of the Bucks County records was likewise fruitless. So the riddle continued unsolved.

The scheduling of this lecture furnished the incentive for one more effort. To some of you I remarked facetiously three months ago that I proposed to find the farm and to announce its location here this afternoon. I have been making a further study, and I have something to announce, but it is not what I had hoped it would be. On the basis of new evidence, unearthed these recent weeks, we have come reluctantly to the conclusion that Franklin was not the author of the letter to Eliot in which the Burlington farm was described, and further-

[3] Duane, Wm., "Letters to Benjamin Franklin from his Family and Friends," 1750–1790. New York, 1859, p. 42.

more, that he neither owned nor operated a farm in New Jersey.

How, you ask, did we arrive at this conclusion? Let me outline briefly the course of our investigation. First of all, we are indebted to Mr. George DeCou for putting us on the right track. In January, 1940, he visited the Yale Library and examined the Eliot letters. He found that the letter relating to the farm was incomplete—the last page was gone and the signature missing; furthermore he detected a difference in the handwriting as compared with the other letters clearly written in Franklin's hand and signed by him. He wrote me of his suspicions and I went to New Haven for a further examination. Mr. Bernard Knollenberg, the librarian, himself, as you know, a keen student of Franklin, aided me in my efforts. We found not only that the handwriting was not Franklin's, but further evidence in the context, when related to statements in other letters, which pointed strongly toward another author.

For example, in a signed letter written December 24 ,1751, Franklin suggested to Eliot that he could get certain agricultural information from John Bartram, the Quaker botanist of Philadelphia, and from Peter Collinson of London. Then followed this significant comment: "And since for want of skill in agriculture I cannot converse with you pertinently on that valuable subject, I am pleased that I have procured you two correspondents who can." [4] Which naturally gives rise to the question: Why would Franklin say this if two years earlier he had written at length about his farm experiments?

Another point of evidence is the absence of local tradition about a Franklin-owned farm. Franklin's temporary printshop at Burlington where in 1727 he printed currency for the province of New Jersey, has long been marked a point of historic interest. If he had really owned a farm near the same place it would certainly have been known in the community at the time, and for a person of his prominence, word would have been passed down from generation to generation. However, there seems to have been no tradition of Benjamin Franklin in the role of farmer in the neighborhood of Burlington.

If not Franklin, then who was the author of the letter? During the search for the so-called Franklin farm, evidence

[4] Smyth, v. 3, p. 61.

was unearthed which led to the irrefutable conclusion that the letter was written by Charles Read, cousin of Deborah Franklin, who was also related to the Logans, the Pembertons and other prominent Philadelphia families. In 1739 Read moved to Burlington and became a dominant figure in the affairs of New Jersey. Between 1740 and 1770, he served as provincial secretary, as justice of the Supreme Court, as member of the Royal Council, and in other offices. In 1747 he purchased a farm of 212 acres in Springfield Township, Burlington County, midway between the present villages of Jobstown and Juliustown, and subsequently acquired an adjacent tract. He named the place *Sharon*, and in 1750 sold it to his friend Daniel Doughty. Many years later it was acquired by Barclay White, father of the late Joseph J. White, New Jersey's premier cranberry grower. The present owner is Mr. Hilary Tilghman.

About twelve years ago there came to light in Burlington County an old farm record book, with miscellaneous entries made between 1746 and 1777. It contained descriptions of numerous farm experiments by the owner, together with the observations and experiences of more than a hundred other persons, and extracts from various books on agriculture. (Among the items, incidentally was a recipe for making glue from sturgeon which Benjamin Franklin had got from a correspondent in London, and sent to the owner of the book.) The cover and flyleaf were gone, and the owner's name did not appear, but the content, the handwriting and other factors all pointed conclusively to Charles Read.

On studying the text, we found a record of the same experiment with red clover that is described in the letter supposedly from Franklin to Eliot. There can be no mistake about it. They coincide to the very day of the month, the length and number of roots, and the same peculiar terminology, e.g. "deep meadow," planted "23rd of August," "came up in four days," Measured "the last of October," "the tap-roots penetrated five inches"—and threw out from the sides "near 30 horizontal roots some of which were six inches long and branched," and in freezing weather the plants "hove out much where thin sown." The identical words, and the identical statistics, in both documents—and in the first person, too. Mr. Knollenberg

and his associates considered this sufficient evidence to change the record in the Yale Library catalogue, and the letter to Eliot was removed from the list of Franklin items.

But was the farm described in the letter, Charles Read's *Sharon?* Read was involved in many speculative enterprises, and had extensive land holdings. Regardless of whether it was owned by Franklin or by Read, we wanted, if possible, to locate the subject of the letter.

Early in March, 1940, accompanied by Dr. Linnwood Lee, head of the New Jersey Soil Conservation Service, I paid a visit to *Sharon*—curious, expectant, but prepared for disappointment. Imagine our mixed feelings when we found that the farm corresponded, to a remarkable degree, with the description in the letter—the 80-acre meadow, the deep black soil, the bluish-green clay, or marl; and the round depression that was the 12-acre pond—here they all were.

But what of the handwriting of the letter? Was it Charles Read's? Although it was similar to some portions of the Read notebook, to the eye of a layman it seemed not to correspond with the general run of Read's letters or his notes. So I enlisted the help of Dr. Samuel Tannenbaum, of New York, Shakesperian scholar and handwriting expert. After a week's study of the Read notebook and a collection of Read letters, and quite unaware of my findings on the Burlington County farm, he came to the conclusion that the letter alleged to be by Franklin is really in the handwriting of Charles Read.[5]

With this body of evidence, we cannot escape the conclusion that Charles Read was the author of the letter to Eliot, which for a century has been attributed to Franklin. So we shall have to revise our concept of Franklin the farmer, and this phase of Franklin's biography will have to be rewritten. Our former concept of Franklin's farm operations has been proved false. I have been guilty, with others, of perpetuating the pleasant myth that the great philosopher had one of America's first experimental farms within the boundaries of New Jersey. Now I am obliged to take back what I have previously written on the subject.

[5] Dr. Tannenbaum's comment, together with other evidence of Read's authorship of the letter and of the notebook, is given in the foreword of "Ploughs and Politicks," by C. R. Woodward, Rutgers University Press, 1941.

The Philadelphia Pasture Lot.

Are we to conclude from this that Franklin never engaged in farm operations, or that he never owned any farm property? Happily the story of Franklin the Farmer is not wholly negative. He did plant seeds and grow crops, to a limited extent. In Deborah Franklin's letters to her husband while he was in England, there is mention of a pasture. In 1747 Franklin wrote to Jared Eliot that the grass seed he had sent him, supposed to be herd-grass, when planted proved to be timothy. Again in 1753 he wrote Eliot, "I wish the Barbary Barley may grow. I have some of it, and have sow'd it; but it seem'd to me to have been cut too green." [6] Perhaps he sowed it in the back yard of his home on High (Market) Street or perhaps in a neighbor's garden. It seems more probable, however, that he planted it on a lot which he rented in Philadelphia. In 1741 he leased from William Coates, a brickmaker, a 2½-acre lot in the Northern Liberties.[7] It was about a mile from Franklin's High Street residence, and lay across what is now North Tenth Street, extending two blocks from the present Fairmount Avenue to Parrish Street. Franklin contracted to pay Coates an annual rental of 3 pounds, 4 shillings and in signing the lease, agreed not to dig clay for the manufacture of bricks, nor to sink any sand pits on the premises without the owner's consent.

It has been suggested that Franklin leased the lot as a suitable site for a glue factory, or for the boiling of linseed oil for the manufacture of varnish. More likely, it seems, he secured it as a pasture for a pony of his son, William, who was then eleven years old. The following spring the pony was lost, and in June, Benjamin advertised for him in *The Pennsylvania Gazette:* "Strayed, about two months ago from the Northern Liberties of this city, a small bay mare branded IW on the near shoulder and buttock. She, being but little and bare-footed, cannot be supposed to have gone far; therefore if any of the town boys find her and bring her to the subscriber, they shall for their trouble have the liberty to ride her when they please." Likely enough the pony had strayed from the pasture lot. It has been suggested also that Franklin may

[6] Smyth, v. 3, p. 128.

[7] Phila. County Deeds, Lib. H7, p. 423.

have had a cow which he kept on the lot, or possibly a horse of his own, but there seems to be no authentic record of either.

Perhaps it was on this lot he planted the barley and other crops as well. Perhaps, too, it was here that he flew his electric kite. The precise site of this famous experiment will probably never be known, but it is reputed to have been in this vicinity.

Franklin's lease on the lot continued at least twenty-four years and probably longer. Entries in his receipt books, now in the Library of the American Philosophical Society, show that while he was in England pleading the cause of the American colonies, the rent was paid by his wife Deborah, who remained in Philadelphia. In one of the letters to her husband written in 1765, she reported that she had the rubbish of lime from their new house spread on the pasture, along with some ashes.[8] Presumably the pasture was on this lot.

Many changes have come to the pasture lot since the philosopher leased it two centuries ago. For years it was an area of tenement houses. Curiously enough, however, the vicinity in 1940, when the lot was identified, had reverted to its former status of an open field. It had recently been chosen for a slum clearance project; the buildings for several blocks were completely razed; and the open squares enclosed with board fences. Here and there some ancient trees suggested its former natural state. Among them were specimens of the rare varnish tree (*Koelreuteria paniculata*), a native of the Far East, possibly the offspring of trees which grew from seeds or young plants imported in Franklin's time.[9]

Although the pasture was only leased, the leasehold seems to have been regarded as equivalent to ownership, as indicated in Deborah Franklin's letters. Also, in an unpublished will dated April 28, 1757, Franklin bequeathed to his son William "my Pasture Ground in the Northern Liberties."

Somewhere the Franklins had apple trees, for in 1758 Benjamin wrote to Deborah, "You have dispos'd of the Apple-Trees very properly," and added, "I condole with you on the Loss of your Walnuts."[10] Sometime later Deborah wrote

[8] Duane, p. 22.

[9] An article about this pasture lot by the present author appears in *The Merck Review* (Rahway, N. J.), I, 1–2, Sept. 1940.

[10] Smyth, v. 3, p. 441.

Benjamin that she had been advised to plant an orchard on the pasture, but she was not disposed to do so.

Besides the rented lot, there was another tract of land which Franklin might have utilized for agricultural purposes. We know now that he did own a farm which was located, not in New Jersey, but in Chester County, Pennsylvania. Information about this place, too, has only recently come to light, and likewise, the information is but fragmentary. Thanks to evidence unearthed by Mr. Charles Montgomery, of Philadelphia, and Mr. John M. Okie, of Lansdowne, Pennsylvania, it appears that the farm embraced two tracts lying close by the village of Kemblesville, in New London Township. No record of the deed has been found in the State or County Archives. However, certain tax records, mortgages [11] and letters together supply conclusive evidence of Franklin's ownership. The New London Township tax lists show that Franklin was assessed for 200 acres of land in 1766, and he appears also in the lists of 1767 and 1771.[12] The farm is mentioned also in two letters among the Franklin Papers of the American Philosophical Society, one of them to Deborah Franklin from George Read of New Castle, the youthful lawyer who became a signer of both the Declaration of Independence and the Constitution.[13] Also Deborah Franklin in an unpublished letter now in the collection of Mr. Franklin Bache, wrote to her husband in London in 1766 about her troubles in managing their land in Chester County.

The records do not show precisely when Franklin acquired the lands, or why. A plausible explanation would be that he took them in settlement of a debt. The transaction seems to have been handled by Deborah, in the absence of her husband, who after a two years' stay in Philadelphia had returned to England in November, 1764. From her letter, we infer that the deed was delivered but she probably never took the trouble to have it recorded, hoping soon to dispose of the place.

From the available sources we gather that the place was acquired from George McCleave, a tavern keeper, that the land was poor and the dwelling in need of repair, that the

[11] Chester Co., Pa., Deeds, Book M, p. 315; N, p. 14, 44; Sheriff's Deed Books, No. 1, p. 39, 68.

[12] *Pennsylvania Archives*, 3rd series, v. 11, p. 246,352,717.

[13] Amer. Phil. Soc., *Franklin Papers*, v. 2, no. 6, p. 1.

tenants had destroyed the fences, that there was neither barn nor stable, that the neighbors were generally poor and worthless, and that the Franklins would be better off if they could get rid of it. Deborah wrote to Benjamin that she had one or two to "hire the place," but she was afraid they would spoil it, because, she said, "there is none but rogues all about." And she added that George Read, who seems to have been acting as her agent, thought it was "the worst place in all the country." [14]

So is our picture of Benjamin Franklin the Farmer deflated! The situation is not without a measure of humor. Instead of the country gentleman, proprietor of an experimental farm in the rich marl-belt of New Jersey, we find him the owner of a dilapidated, worn-out place in a then undesirable neighborhood!

It seems quite improbable that Franklin ever operated the Kemblesville farm, or carried on any experiments there. When he disposed of it we have not learned. After 1757 he spent only 8 of the remaining 33 years of his life in America—a 2-year interlude from 1762 to 1764; 17 months in 1775–76, and somewhat less than five years after his return from France in 1785 until his death in 1790. The Kemblesville farm seems to have been acquired after his return to England in 1764. Between 1766 and 1771, the years he was on the tax lists, he was in England, and the responsibility for the place was carried by the faithful and reliable Deborah. During his brief Philadelphia sojourn in 1775–76, he was so completely engrossed with the political and military activities of the Revolution as to preclude adventures in agriculture, and in the meantime Deborah had died. After his final homecoming in 1785, he was so ill and feeble as to make travel a burden, and a trip to a run-down farm 40 miles from Philadelphia would seem to be out of the question.

In Franklin's later years, he acquired other lands—in Nova Scotia and on the Ohio. But obviously these were for speculative investment rather than for agricultural purposes.

Eighteenth Century Farm Demonstration.

There remains to be mentioned one last incident of Franklin the Farmer—his well-known demonstration of the benefits of

[14] "Deborah Franklin to Benjamin Franklin," Jan. 12, 1766; in collection of Mr. Franklin Bache.

land plaster. It has become a well-established Franklin tradition, a worthy companion to the story of the electric kite. But its source is not to be found in any of Franklin's published works. For it, we are indebted to Jean Antoine Claude Chaptal, Compte De Chanteloup, author of the French work, "Chimie Appliquée a l'Agriculture," published in Paris in 1825. I quote from the English translation of 1835:

"The use of plaster, or gypsum, which has become common in Europe as a manure, is one of the most important improvements that has ever been made in agriculture. It has even been introduced into America, where it was made known by Franklin upon his return from Paris. As this celebrated philosopher wished that the effects of this manure should strike the gaze of all cultivators, he wrote in great letters, formed by the use of the ground plaster, in a field of clover lying upon the great road to Washington, 'This has been plastered.' The prodigious vegetation which was developed in the plastered portion led him to adopt this method. Volumes upon the excellences of plaster would not have produced so speedy a revolution. From that period the Americas have imported great quantities of plaster of Paris." [15]

Where was the field on which the demonstration was staged? What was the "great road to Washington"? According to Chaptal, the event must have occurred after 1785. William Temple Franklin had settled on the Rancocas farm, but there is no evidence that Benjamin ever visited his grandson there. Also, since Temple's country seat was not situated on a main highway, it can be eliminated as the site of the demonstration. And we have already observed the improbability that Franklin ever visited the Kemblesville farm. Might it have been done on the leased pasture in the Northern Liberties? This seems doubtful. We do not know that Franklin continued his lease of the pasture after the Revolution. Furthermore, so far as we know, no main highway ran beside it. Even if there were, a road lying north of the center of the city would scarcely be called "the main highway to Washington." Besides, the city of Washington was not founded until after Franklin's death.

[15] Chaptal, J. A. C., "Chymistry Applied to Agriculture," 1835, p. 73.

The account does not say that Franklin spread plaster on a field of his own. If he actually conducted the demonstration as late in life as Chaptal indicates it seems more probable that he borrowed for the purpose the field of a friend along the Chester Road near the outskirts of Philadelphia.

We shall probably never know the precise answer. Presumably Chaptal got the story from some friend or correspondent of Franklin's in France. We cannot confirm it from Franklin's known works; nor can we dispute it. Let's hope it will never be disproved. It is too good a story for debunking. We should like to see it stand for all time.

You will agree, I think, that contrary to my natural inclination, I haven't been able to make a very strong case for Franklin the Farmer. But this need not subtract one jot or one tittle from Franklin's great service as an Agricultural Leader. It is to this phase of his career we shall now direct our attention.

II. FRANKLIN THE AGRICULTURAL LEADER.

Benjamin Franklin exemplified in a remarkable degree the modern agencies of agricultural progress. As an individual he performed many of the major functions now sponsored by the Government in its national agricultural program. He anticipated something of the work of the agricultural experiment station, of the consular service and of the agricultural educator. Perhaps the most distinctive agency for the promotion of agriculture in America is our system of Land-Grant Colleges, which we popularly call the state agricultural colleges. These institutions, supported jointly by state and federal funds, perform a three-fold function; viz., research, resident instruction, and extension. They coöperate closely with the United States Department of Agriculture, which, in addition to its extensive policing powers, also conducts a great program of research, and is engaged in the introduction of new plants, and other measures for the improvement of agriculture. Let us see how Franklin touched these same fields of activity even before the birth of our government.

Long before the movement for farm organization took hold either in Europe or in America, Franklin recognized the possibilities of agricultural societies as a means of discovering and

extending agricultural knowledge. In his plan for the American Philosophical Society, formulated in 1743, he listed among its chief objects, "all new-discovered plants, herbs, trees, roots, their virtues, uses &c.; methods of propagating them, and making such as are useful, but particular to some plantations, more general; improvements of vegetable juices, as ciders, wines &c. . . . draining of meadows . . . nature of the soil and productions; new methods of improving the breed of useful animals; introducing other sorts from foreign countries; new improvements in planting, gardening, and clearing land; and all philosophical experiments that let light into the nature of things, tend to increase the power of man over matter, and multiply the conveniences or pleasures of life." [16] When the society got under way, one section was devoted to "husbandry and American improvements." [17]

Here was the germ of the American agricultural experiment station, and the agricultural extension service. As if an outgrowth of the Philosophical Society, in 1785 a group of prominent citizens in and about Philadelphia formed The Philadelphia Society for Promoting Agriculture. This was the first successful effort in America to establish a society devoted exclusively to agriculture. Happily, the society has had a long and notable history, and is still a vigorous and going concern. If Franklin had been in America at the time of its founding, he almost certainly would have been among the charter members. However, he did not return from Paris until 7 months later. Shortly thereafter he joined the Society and two years later his grandson, William Temple, was elected to honorary membership. Because the Agricultural Society confined its activities to the one special field, it could deal more effectively with the agricultural interests outlined by Franklin than the Philosophical Society was ever able to do.

Also Franklin was more than a century in advance of his time, in advocating instruction in the science and practice of agriculture. In his proposal for the Philadelphia Academy, forerunner of the University of Pennsylvania, made in 1749, he included the suggestion:

"While they are reading Natural History, might not a

[16] Smyth, v. 2, p. 229–230.

[17] *Trans. Amer. Phil. Soc.*, 1 (Phila., 1771), p. 117–280.

little *Gardening, Planting, Grafting, Inoculating*, etc. be taught and practiced; and now and then Excursions made to the neighbouring Plantations of the best Farmers, their methods observ'd and reason'd upon for the Information of Youth? The Improvement of Agriculture being useful to all, and Skill in it not Disparagement to any." [18]

This is believed to have been the first suggestion by an American that agriculture be studied in school. His advice in this matter was not followed by the directors of the academy, but subsequent developments show that he was proposing a sound scheme of vocational education. We have seen also that he was far ahead of his time in agricultural extension, for his object lesson with land plaster has been called the first instance of farm demonstration on record.

Agricultural Missionary.

Quite independently of any formal organization, however, Franklin quietly went about his investigations, and the dissemination of useful information. His travels about the colonies as postmaster-general gave him an opportunity to note the farm practices of different regions, and he always had his eye open for new things. For example, while in Virginia he gathered some broom-corn seed and sent it to his sister in Rhode Island to be distributed among friends. He read Jared Eliot's "Essays upon Field Husbandry," he visited Eliot, exchanged seeds and plants with him and corresponded with him on agricultural subjects. Fencing was a problem the colonial farmer always had with him. On Long Island Franklin saw a new kind of hedge that caught his fancy. So he wrote to Eliot:

"I would know every particular relating to this Matter, as the best Thickness, Height, and Slope of the Bank; the Manner of erecting it, the best Time for the Work, the Way of planting the Hedge, the Price of the Work to Labourers per Rod or Perch, and whatever may be of Use for our Information here, who begin in many Places to be at a Loss for Wood to make Fence with." [19]

There is the legend, seemingly well authenticated, that the

[18] Smyth, v. 2, p. 395.
[19] Smyth, v. 3, p. 31.

introduction of the yellow willow into America was due to him. The story is told that a basket in which some foreign commodity had been imported, having been thrown into a creek, was observed by Franklin to be putting forth green sprouts. He caused the sprouts to be planted on the ground later occupied by the Philadelphia Customs House. They took root and grew, and proved to be the yellow-willow.[20]

During his residence in England, and subsequently in France, he came in touch with European practices, and passed along his observations for the benefit of his American compatriots. His membership in the Royal Society of London and the London Society of Arts put him in touch with many Englishmen who were interested in agriculture and botany—men like Peter Collinson and Dr. John Fothergill. These Englishmen wanted American plants and seeds, and Franklin wrote to John Bartram and Humphry Marshall for them. Likewise he coöperated with the English doctors who were anxious to get herbs for medicinal purposes. He secured for John Bartram his appointment as American botanist to George III. He studied books and pamphlets by English writers on agriculture, ordered them for the American Philosophical Society, and distributed them among his former friends. On excursions about the countryside to seek relaxation from the formalities of court and tension of diplomatic circles, he was quick to perceive new varieties of plants, along with new ideas of culture, to pass on to his American friends. On one occasion he sent John Bartram from England seeds of new varieties of turnips, cabbage and peas; again he forwarded to his wife some naked oats, recommended for oatmeal, and some Swiss barley, "six rows to an ear," with the request that she divide it among his friends Hugh Roberts, Samuel Rhoades, John Bartram and others. At another time it was some upland rice from China that he wanted tried out in America. Again he procured some scions of the Newtown Pippin apple from Pennsylvania, and some hickory nuts, walnuts and chestnuts, for friends in France. Then it was Penshurst peas, and again a new sort of beans that he sent home across the water.

Of the many new varieties of plants that he introduced

[20] Smyth, v. 1, p. 84–85.

into the New World, two are of special economic value today. In 1772 he got some seeds of rhubarb from Scotland, and sent them to Bartram. This, we are told, was the first rhubarb on record in America. Concerning it he wrote:

"I hope the Rhubarb you have sown and distributed will be taken care of. There seems to be no doubt of its doing well with us as in Scotland. Remember that for Use the Root does not come to Perfection of Power and Virtue in less than Seven Years. The Physicians here who have try'd the Scotch, approve it very much, and say it is fully equal to the best imported." [21]

The other crop was Scotch kale, one of the two varieties of kale now grown commercially in the United States.

Alfalfa, then called "lucerne," also commanded his interest and he was a champion of Indian corn as the most profitable grain for the colonies. He wrote at length during his stay in England on the merits of this crop, urging prospective settlers to try corn in preference to the more familiar wheat.

In the ancient controversy on the relative merits of the horse and the ox as a farm work animal he sided with the latter, for did it not provide both labor and meat? "I have observed in America," he wrote Lord Kames, "that the farmers are more thriving in those parts of the country where cattle are used, than in those where the labour is done by horses." [22]

While in France his advice was sought on various matters agricultural. He secured American seeds for the Compte de Buffon, for the *Jardin des Plantes*. The Royal physician from the court of Vienna wrote him about the diseases of wheat. He gave information on the construction of a drill plow, and on machines for the pulling of tree stumps. He was asked how to protect fruit trees from frost. He discoursed on the value of practical methods for controlling insects, befriending birds as the destroyers of the pests.

Franklin was interested in the culture of hemp, flax and silk, and believed that these crops had great possibilities in America. Time and again he used his efforts to encourage the

[21] Smyth, v. 5, p. 443.
[22] Smyth, v. 5, p. 194.

growing of silk. The British Government offered a bounty on silk produced in the colonies, and similar bounties were voted by the Pennsylvania and New Jersey assemblies, doubtless in some measure due to his influence.

While in England he gathered information on silk culture and sent it to America. In 1772 the "Filature of Philadelphia," a company organized for the manufacture of silk, sent Franklin several trunks full of their product, mostly for sale, but some of it intended for a gift to the Queen. The presentation was made by Franklin through his friend Sir John Pringle, physician of the Royal family. Subsequently his records show that in 1773 he received at auction 19 shillings sixpence per pound for American silk.

Franklin advanced many reasons why Americans should grow silk. Writing to Mrs. Franklin, he said, "I shall honour very much every young Lady that I find on my Return dress'd in Silk of their own raising." [23] But the Revolutionary war for the time put an end to the commercial production of silk, which otherwise might have become of considerable importance.

The thoroughness and diligence which marked Franklin's endeavors as an agricultural missionary are revealed in an interesting anecdote which John Adams recorded in his diary in 1760. Adams got the story from Edmund Quincy, of Boston, the recipient of favors at Franklin's hand. It is as follows, in Adams' words:

"Mr. Quincy told a remarkable instance of Mr. Benjamin Franklin's activity and resolution to improve the productions of his own country; for from that source it must have sprung, or else from an unheard of stretch of benevolence to a stranger. Mr. Franklin happening, upon a visit to . . . friends, . . . was asked . . . to drink tea at Mr. Quincy's. The conversation turned upon the qualities of American soil, and the different commodities raised in these provinces. Among the rest, Mr. Franklin mentioned that the Rhenish grape vines had been introduced into Pennsylvania, and that some had been lately planted in Philadelphia, and succeeded very well. Mr. Quincy said, upon it, 'I wish I could get some into my garden; I doubt not they would do very well in this province.'

[23] Smyth, v. 5, p. 373.

Mr. Franklin replied, 'sir, if I can supply you with some of the cuttings, I shall be glad to.' Quincy thanked him and said, 'I don't know but some time or other I shall presume to trouble you.' And so the conversation passed off. Within a few weeks, Mr. Quincy was surprised with a letter from some of Franklin's friends in Boston, that a bundle of these Rhenish slips were ready for him; these came by water. Well, soon afterwards he had another message that another parcel of slips were left for him by the post. The next time Mr. Franklin was in Boston, Mr. Quincy waited on him to thank him for his slips; 'but I am sorry, sir, to give you so much trouble.' 'O, sir,' says Franklin, 'the trouble is nothing to me, if the vines do but succeed in your province. However, I was obliged to take more pains than I expected, when I saw you. I had been told that the vines were in the city, but I found none, and was obliged to send up to a village, seventy miles from the city, for them.' Thus, he took the trouble to hunt over the city, and not finding vines there, he sends seventy miles into the country, and then sends one bundle by water, and, lest they should miscarry, another by land, to a gentleman whom he owed nothing and was but little acquainted with, purely for the sake of doing good in the world by propagating the Rhenish vines through these provinces. And Mr. Quincy has some of them now growing in his garden." [24]

Agricultural Economist.

Even more important than his plant introductions, at least from the point of view of the economist and the sociologist, were his contributions to agriculture as a manner of life. He seemed constantly alert to ways and means of advancing the economic and social status of the agricultural population. For example, to protect the farmer against the destructive forces of nature he proposed a scheme of crop insurance. Following a disastrous storm in France in 1788 he wrote: "I have sometimes thought that it might be well to establish an office of insurance for farms against the damage that may occur to them from storms, blights, insects, etc. A small sum paid by a number would repair such losses and prevent much poverty and distress." [25] This sounds more like the agri-

[24] Adams, C. F., "The Works of John Adams," Boston, 1850, v. 2, p. 81–82.
[25] Smyth, v. 9, p. 674.

cultural economics of the present day than of the Eighteenth Century.

Franklin, the economist, placed agriculture first among the industries. He believed with the Physiocrats of France, that agriculture is the chief source of wealth; that it is from the soil we derive our real riches. Thus in 1768 he wrote to a friend in true physiocratic vein: "Agriculture is truly *productive of new wealth;* manufacturers only change forms, and whatever value they give to the materials they work upon, they in the meantime consume an equal value in provisions, &c. So that riches are not *increased* by manufacturing. . . ." [26] As late as 1784 he was still of the opinion that the "first Elements of Wealth are obtained by Labour, from the Earth and Waters" and drew the striking figure, "He that puts a Seed into the Earth is recompens'd, perhaps, by receiving twenty out of it; and he who draws a Fish out of our Waters, draws up a Piece of Silver." [27]

A bushel of wheat, or the labor required to produce it, rather than an ounce of silver, he claimed, might well be the standard of economic values.

"There seem to be but three ways for a nation to acquire wealth," he wrote in a passage quoted by Dr. Spiller in the last lecture in this series. "The first is by *war*, as the Romans did, in plundering their conquered neighbours. This is *robbery*. The second by *commerce*, which is generally *cheating*. The third by *agriculture*, the only *honest way*, wherein man receives a real increase of the seed thrown into the ground, in a kind of continual miracle, wrought by the hand of God in his favour, as a reward for his innocent life and his virtuous industry." [28]

Like Jefferson, he was a great admirer of the New England system of land settlement as opposed to the Proprietary system in Pennsylvania and New Jersey. The small independent farmers, he believed, formed the social and political backbone of the new nation. He lauded "the country habits of temperance, frugality, and industry, which give the most pleasing prospect of future national felicity." [29]

[26] Smyth, v. 5, p. 102.
[27] Smyth, v. 9, p. 246; v. 10, p. 122.
[28] Smyth, v. 1, p. 148–149.
[29] Smyth, v. 10, p. 61.

Still he did not go to extremes in championing the common man. Although of the anti-proprietary party, he sought after the Revolution for an equitable adjustment of the proprietors' rights. Mid conflicting forces he clung persistently to the middle road of "constructive liberalism." Had he lived another generation he probably would have been found among the leaders in the camp of "Jeffersonian agrarian democracy." He foresaw the great promise of American expansion westward, and recognized that one of the pressing needs of the future would be adequate market outlets for the produce of western farms.[30]

Agricultural Philosopher.

The picture would not be complete without a word about Franklin's agricultural philosophy. His insight into rural life is reflected in the homely sayings of Poor Richard. The almanac no doubt exercised an important influence upon agricultural practices. Next to the Bible, probably, it was the most commonly read publication in colonial farm homes. Poor Richard could talk the language of the farmer. Some of the best known of his sayings are drawn from farm experience. For example:

> Plough deep while sluggards sleep,
> And you shall have corn to sell and to keep.
>
> He that by the plough would thrive,
> Himself must either hold or drive.
>
> The rotten apple spoils his companions.
>
> A sleeping fox catches no poultry.
>
> The worst wheel of the cart makes the most noise.

From the days when Poor Richard composed his epigrams to the time of the constitutional convention was a long and epic period, yet in the elder statesman who returned from his last European mission, we find a rural philosophy that had become mellowed and deepened through the years.

Near the close of life, looking back over one of the most extraordinary of careers, which had embraced the several roles

[30] Ross, Earle D., "Benjamin Franklin as an Eighteenth Century Agricultural Leader." In *Jour. Pol. Econ.*, **37**, 52–72 (1929).

of printer, publisher, merchant, scientist, soldier, statesman and diplomat, and had touched all manner of activities, both rural and urban, on both sides of the Atlantic, he concluded that agriculture was "the most useful, the most independent, and therefore the noblest of Employments." [31] He took delight in seeing William Temple, the apple of his eye, established on the ex-governor's estate in Burlington County. Giving rein to his sentiments in a letter to General Lafayette, he wrote in 1787: "My grandson . . . is at his estate in the Jerseys, and amuses himself with cultivating his lands. I wish he would seriously make a business of it, and renounce all thoughts of public employment, for I think agriculture the most honourable, because the most independent, of all professions." [32]

American agriculture was enriched by Benjamin Franklin's contributions, and through his leadership the march of agricultural progress was advanced both at home and abroad. It seems appropriate to close with a tribute to Franklin from a work on agriculture by a native of France residing in America. We have observed Franklin's active interest in the growing of Rhenish grapes in this country and his efforts to promote wine culture. In 1827 Alphonse Loubat published a handbook entitled "The American Vine Dressers' Guide," which he dedicated to the memory of Benjamin Franklin. Although the text appears in both French and English, the dedicatory address is in French alone. I give you the translation of one paragraph:

"O Franklin, you who taught us the way to keep grapes in all their freshness; you who were one of the fathers of domestic economy, you will stand by my vineyard; your shadow will come to wander beneath its branches, weighted down with fruit; your kind spirit will gaze with delight upon the hills of your dear fatherland, adorned with gifts from Bacchus; and in the dwelling-place of the righteous you will rejoice in hearing the echoes from the dales which saw your birth, to repeat the songs of joy of the happy grape-gatherer." [33]

[31] Smyth, v. 9, p. 491.
[32] Smyth, v. 9, p. 571.
[33] Op. cit., p. iv.

I. EVALUATION OF THE PEANUT AS A CASH CROP.

II. IMPORTANCE OF THE PEANUT FROM A BIOCHEMICAL STANDPOINT, ESPECIALLY FROM THAT OF NUTRITION.

BY

SAMUEL L. JODIDI, Ph.D.

(*Continued from August issue.*)

II. IMPORTANCE OF THE PEANUT FROM A BIOCHEMICAL STANDPOINT, ESPECIALLY FROM THAT OF NUTRITION.

The Concept of a Complete Food.

The importance of food to man for maintaining life with all its functions is self-evident and needs no emphasis. Of the twenty odd amino acids known only ten have definitely been recognized to be absolutely necessary for maintenance and growth because they cannot be synthesized in the animal organism, while the rest of them are not indispensable (15, p. 299; 16, p. 130). Thus, Osborne and Mendel were among the first to show that the protein lactalbumin (from milk) is superior to the protein edestin (from hempseed) for promoting growth (13, p. 356), one of the reasons being that the former contains much more of the essential amino acid lysine (8.10 per cent.) than the latter (1.65 per cent.). The same authors as well as McCollum have demonstrated that the proteins of milk have a higher nutritive value and are especially more important for growth than the proteins of cereal grains (14, p. 119; 11, p. 156). For instance, the protein casein (from milk) is for growth superior to the protein gliadin (from wheat) because the former contains more essential amino acid and in larger proportions than the latter. Thus casein and gliadin, in the order named, contain the following percentages of the indispensable amino acids: valine, 7.20 and 0.21; leucine, 9.35 and 6.6; arginine, 3.81 and 2.9; lysine, 7.61 and 0.6; histidine, 2.50 and 0.61; phenylalanine, 3.20 and 2.35; tryptophan, 1.50 and more than a trace.

From the work of Johns and Jones (6, 7, 8) it is known that the two proteins occurring in peanuts, arachin and

conarachin, contain significant proportions of the indispensable amino acids. Thus, arachin contains the following percentages of the necessary amino acids: valine, 1.1; leucine, 3.9; phenylalanine, 2.6; arginine, 13.5; histidine, 1.9; lysine, 5.0; trypotophane, 0.9. The percentages of indispensable amino acids in conarachin are as follows: lysine, 6.0; histidine, 1.8; arginine, 14.6; tryptophane, 2.1. Jones and Horn have also estimated the proportionate occurrence of arachin and conarachin in the peanut (9). Therefore, not only do peanuts represent an adequate food, but due to the high biological value of their proteins, especially to the high lysine content in their proteins, arachin (5.00 per cent.) and conarachin (6.00 per cent.) peanut meal when added to foods poor in or devoid of lysine, such as wheat and corn flour, will notably improve their nutritive value.

From the foregoing it is evident that proteins differ essentially in their amino acid make-up depending on whether they are just to support or keep up the maintenance of the body weight, or also to promote growth. That functions other than growth, such as reproduction and detoxication, may require amino acids in addition to the ten indispensable acids, was pointed out by Rose (15, p. 299).

Discussion and Interpretation of Data.

In Table 5 are given the chemical composition and calories of peanuts as well as of bread, potatoes and meat.

A glance at Table 5 shows that the chemical composition of the different peanut varieties is fairly similar. Thus, the difference between the highest (50.00 per cent.) and the average fat content (47.08 per cent.), on air-dry basis, is 6.2 per cent. of the average value. Similarly, the difference between the highest (26.82 per cent.) and average protein content (25.62 per cent.), on air-dry basis, amounts to 4.7 per cent. As to the energies, it will be seen that the small Virginia Runner yields 2,784 calories per pound which is less than two per cent. below the average Jumbo Virginia Runner (2,829), the latter yielding calories 2.7 per cent. below the Spanish variety. Of them all the most striking fact is that all peanut varieties yield calories far in excess of bread, potatoes and meat.

TABLE 5.

Chemical Composition and Calories of Peanut Kernels as Compared with Those of Bread, Potatoes and Meat.

Number.	Kind of Food.	Variety.	Basis.	Water %.	Dry Matter %.	Ash %.	Fat (Ether Extract) %.	Protein %.	Crude Fiber %.	Total Carbohydrates %.	Calories per Pound.	Citations.
1	Peanut kernel	Small Virginia Runner	Air-dry	3.33		2.29	45.35	25.98	2.73	20.32	2,691	5, pp. 304–309
do.	do.	do.	Water-free		96.67	2.37	46.91	26.87	2.82	21.03	2,784	
2	do.	Jumbo Virginia Runner	Air-dry	2.95		2.48	46.02	26.82	2.14	19.57	2,720	do.
do.	do.	do.	Water-free		97.05	2.56	47.42	27.64	2.21	20.17	2,803	
3	do.	do.	Air-dry	3.10		2.24	47.88	26.14	2.13	18.51	2,765	do.
do.	do.	do.	Water-free		96.90	2.31	49.41	26.98	2.20	19.10	2,853	
4	do.	do.	Air-dry	3.25		2.33	46.46	26.29	2.17	19.50	2,727	do.
do.	do.	do.	Water-free		96.75	2.41	48.02	27.17	2.24	20.16	2,819	
5	do.	do.	Air-dry	3.27		2.15	47.00	24.85	2.04	20.69	2,745	do.
do.	do.	do.	Water-free		96.73	2.22	48.59	25.69	2.11	21.39	2,838	
6	do.	do.	Air-dry	3.48		2.37	46.80	26.36	2.15	18.84	2,731	do.
do.	do.	do.	Water-free		96.52	2.46	48.49	27.31	2.23	19.51	2,830	
Average (1–6) on air-dry basis				3.23		2.31	46.59	26.07	2.23	19.58	2,730	
Average (1–6) on water-free basis					96.77	2.39	48.14	26.94	2.30	20.23	2,821	

TABLE 5.—*Continued*

Number.	Kind of Food.	Variety.	Basis.	Water %.	Dry Matter %.	Ash %.	Fat (Ether Extract) %.	Protein %.	Crude Fiber %.	Total Carbohydrates %.	Calories per Pound.	Citations.
7	Peanut kernel	Spanish	Air-dry	4.2		2.6	50.0	22.9	2.1	18.2	2,787	1, p. 291
do.	do.	do.	Water-free		95.8	2.7	52.2	23.9	2.2	19.0	2,909	
Average (1–7) on air-dry basis				3.37		2.35	47.08	25.62	2.21	19.37	2,738	
Average (1–7) on water-free basis					96.63	2.43	48.72	26.51	2.28	20.05	2,834	
8	Bread (French)	No milk or shortening	Air-dry	34.1		1.3	1.0	8.4	0.3	55.2	1,195	3, p. 28
do.	do.	do.	Water-free		65.9	2.0	1.5	12.7	0.5	83.3	1,803	
9	Potatoes (fresh)	Tubers, whole or peeled	Air-dry	77.8		0.99	0.1	2.0	0.4	19.1	387	3, p. 71
do.	do.	do.	Water-free		22.2	4.5	0.5	9.0	1.8	86.0	1,744	
10	Meat (fresh beef)	Medium grade, 66 per cent. lean	Air-dry	50		0.7	18.0	14.7		0.0	1,002	3, p. 22
do.	do.	do.	Water-free		50.0	1.4	36.0	29.4		0.0	2,003	

In looking over Table 6 it will be seen that the composition of the peanuts is quite different from that of all other legumes under consideration. Thus, the fat content of the peanuts is far higher than that of the other legumes, being even two and one-half times as large as that of the soybeans in spite of the fairly high fat content of the latter. On the other hand, the proportion of carbohydrates in the peanuts is very much smaller than in the other legumes, excepting the soybeans, while in the protein content the peanuts stand in the middle, approaching the protein content of the peas and lentils but being below that of the soybeans and above that of the lima beans. It is because of the higher fat content of the peanuts that their calorific value is very much above that of the other legumes.

Table 7 shows that the fat content of the peanuts is lowest as compared with that of the other nuts under examination. The reverse holds good for the protein proportion, which is highest in the peanuts, all the other nuts having a considerably smaller protein content. As to the carbohydrates, it will be observed that the peanuts have the highest percentage, with the exception of the almonds, whose carbohydrate content is equal to that of the peanuts.

Here again the energy value of the nuts is chiefly determined by their fat content; those having a larger proportion of fat have also a larger energy value. Thus, the pecan nuts that have the highest fat content (75.3 per cent.) on water-free basis show also the highest calorific value (3,493). This is followed, in the order named, by the Brazil nuts, English walnuts, hazelnuts, almonds, and peanuts, whose fat contents and calorific values are, respectively, 69.6 and 3,328; 66.6 and 3,292; 64.8 and 3,232; 56.8 and 3,046; 48.72 and 2,834.

Accepting 3,200 calories per day per adult as standard, which is reasonable, and taking into consideration the figures presented in Table 5 it will be found that the stated amount of energy is furnished by 1.13 lbs. of peanuts. This compares with 1.60 lbs. of meat, 1.77 lbs. of bread and 1.83 lbs. of potatoes. From Table 6 it follows that 3,200 calories are furnished by 1.13 lbs. of peanuts, which compares with 1.76 lbs. of soybeans, 1.79 lbs. of peas, 1.80 lbs. of lima beans, and 1.80 lbs. of lentils. Table 7 shows that the 3,200 calories

TABLE 6.

Chemical Composition and Calories of Peanut Kernels as Compared with Those of the Seeds of Lentils, Peas, Lima Beans, and Soybeans.

Kind of Food.	Basis.	Water %.	Dry Matter %.	Ash %.	Fat (Ether Extract) %.	Protein %.	Crude Fiber %.	Total Carbohydrates %.	Calories per Pound.	Citations.
Peanut kernel (average analysis)	Air-dry	3.37		2.35	47.08	25.62	2.21	19.38	2,738	5, pp. 304–309; 1, p. 291
Do	Water-free		96.63	2.43	48.72	26.51	2.29	20.05	2,834	
Lentil (*Ervum Lens*), whole	Air-dry	11.2		3.2	1.0	24.7	3.3	59.9	1,575	3, p. 54
Do	Water-free		88.8	3.6	1.1	27.8	3.7	67.5	1,774	
Pea (*Pisum sativum*), fresh, shelled	Air-dry	74.3		0.92	0.4	6.7	2.2	17.7	460	3, p. 63
Do	Water-free		25.7	3.58	1.6	26.1	8.6	68.9	1,789	
Lima bean (*Phaseolus lunatus*), shelled, immature	Air-dry	66.5		1.71	0.8	7.5	1.5	23.5	595	3, p. 21
Do	Water-free		33.5	5.10	2.4	22.4	4.5	70.1	1,776	
Soybean (*Soja hispida*), fresh, shelled	Air-dry	67.0		1.5	6.5	12.5	1.5	6.0	600	3, p. 79
Do	Water-free		33.0	4.5	19.7	37.9	4.5	18.2	1,822	

TABLE 7.

Chemical Composition and Calories of Peanut Kernels as Compared with Those of Kernels of Hazelnuts, English Walnuts, Brazil Nuts, Almonds, and Pecan Nuts.

Kind of Food.	Nature of Sample.	Basis.	Water %.	Dry Matter %.	Ash %.	Fat (Ether Extract) %.	Protein %.	Crude Fiber %.	Total Carbohydrates %.	Calories per Pound.	Citations.
Peanut (average analysis)		Air-dry	3.37		2.35	47.08	25.62	2.21	19.38	2,738	5, pp. 304–309; 1, p. 291
Do.		Water-free		96.63	2.43	48.72	26.51	2.29	20.05	2,834	
Hazelnut (*Corylus Avellana*)	Including filberts	Air-dry	6.0		2.7	60.9	12.7	3.4	17.7	3,040	3, p. 49
Do.		Water-free		94.0	2.9	64.8	13.5	3.6	18.8	3,232	
English Walnut (*Juglans regia*)		Air-dry	3.3		1.7	64.4	15.0	2.1	15.6	3,185	3, p. 88
Do.		Water-free		96.7	1.8	66.6	15.5	2.2	16.1	3,292	
Brazil nut (*Bertholletia excelsa*)		Air-dry	5.3		3.4	65.9	14.4	2.1	11.0	3,150	3, p. 28
Do.		Water-free		94.7	3.6	69.6	15.2	2.2	11.6	3,328	
Almond (*Amygdalus communis*)	Unblanched	Air-dry	4.7		3.0	54.1	18.6	2.7	19.6	2,900	3, p. 18
Do.		Water-free		95.3	3.1	56.8	19.5	2.8	20.6	3,046	
Pecan (*Hicoria pecan*)		Air-dry	3.0		1.6	73.0	9.4	2.2	13.0	3,385	3, p. 63
Do.		Water-free		97.0	1.7	75.3	9.7	2.3	13.4	3,493	

which are furnished by 1.13 lbs. of peanuts compare to 0.92 lb. of pecan nuts, 0.96 lb. of Brazil nuts, 0.97 lb. of English walnuts, 0.99 lb. of hazelnuts, and 1.05 lbs. of almonds. From Tables 6 and 7 it is fairly evident that in their chemical composition and calorific value the peanuts appear to stand closer to the nuts than to the legumes.

SUMMARY AND CONCLUSION.

An increase in cultivation of the peanut has much to recommend it. In the first place it would make this country self-sufficient as far as this important food is concerned. In the second place the excess of peanuts not consumed as such could be converted into peanut oil. Thus, the United States would no longer be dependent upon other countries for the importation not only of peanut oil but of olive oil as well.

The data in this paper appear to justify the statement that, in general, the peanut may easily be considered as a fairly complete food from the standpoint of its chemical composition and its ready digestibility (1, p. 289). Thus, it contains an abundance of energy-producing constituents in the form of fat and carbohydrates to meet the demands for heat and the activities of the bodily machine; fairly large quantities of tissue-building components in the form of proteins to meet the requirements of the growing young organism and of the wear and tear of the fully developed organism; it contains several vitamins of the important so-called "vitamin B complex" (10, 17, 18), but has a rather moderate content of mineral ingredients, though notably more than wheat flour.

As to the quality of the peanut components it was observed that the oil extracted from the peanut kernel has a sweet taste and scent, which stands in full agreement with the observations of others.

APPENDIX.

A clear-cut picture of the relative energy values of the different foods may be obtained by designating the calorific value of peanuts as 100. The values of the other foodstuffs under consideration are as follows: Pecan nuts, 123; Brazil nuts, 117; English walnuts, 116; hazelnuts, 114; almonds, 107;

meat, 71; soybeans, 64; bread, 64; peas, 63; lima beans, 63; lentils, 63; potatoes, 62. These figures show that in calorific value the peanuts are very much superior to the staples, potatoes, bread and meat, and to all the legumes, but inferior to the other nuts.

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WASHINGTON, D. C.

A THEORY OF BRAKES, AN EXAMPLE OF A THEORETICAL STUDY OF WEAR.

BY

I. OPATOWSKI.*

ABSTRACT.

The bases for a theoretical study of wear by friction were given by Th. Reye.[1] Starting from the obvious assumption that the more work done by the friction forces the more material is removed from the worn surface, he was able first to investigate theoretically the mechanics of different types of bearings. The importance of wear by friction is in some mechanical organs, particularly brakes, so great, that the ideas which Reye published 80 years ago still form today the theoretical basis for their design. The present paper is an attempt to go further in these investigations by taking into account two factors which up to now have been neglected: (1) the elastic deformation of the body subjected to wear and (2) the continuous change of its shape in consequence of the wear. The study, which is carried out in a case where the wear effect is particularly evident, the case of brakes, leads to formulas for the determination of the working features of this organ. It explains also in a very clear manner why a certain geometric position of the braking organs is necessary in order to obtain a progressive braking action and why this becomes worse as the wear goes on.

The brakes are here taken in their simplest form of a type commonly used in automobiles: a hollow cylinder, the brake drum (of which a part DD is drawn in Fig. 1) rotates about its axis A (the arrow in Fig. 1 shows the direction of rotation). Inside DD a strip $SSLL$, the brake shoe lining, having the shape of a piece of ring of rectangular cross section, is fixed on the brake shoe, whose external surface is a cylindrical circular surface SS. (For clarity the actual proportions of various parts are changed in Fig. 1.) The surfaces DD and SS are assumed as rigid with respect to the strip $SSLL$ which is taken as elastic. When the brake is put into action SS rotates about an axis O parallel to A, so that $SSLL$ is compressed against DD. The contact pressure gives rise to friction forces tangential to DD, whose moment M about A

* At present at Armour Research Foundation.

[1] Th. Reye, "Zur Theorie der Zapfenreibung," *Civilingenieur* (1860), vol. 6, pp. 235–254, or C. Bach, "Maschinenelemente," vol. 1, ed. 10, Leipzig 1908, pp. 488–497.

determines the braking action. It is assumed that before the wear started the brake shoe lining $SSLL$ was of constant thickness, so that the brake shoe lining surface was circular cylindrical with axis in X. The drum surface DD is assumed also as circular with axis in A. The wear of the drum is neglected. Let KK be the external surface of the brake shoe lining after a certain time t of braking, so that $LLKK$ is the volume worn by friction. KK is not necessarily an arc of

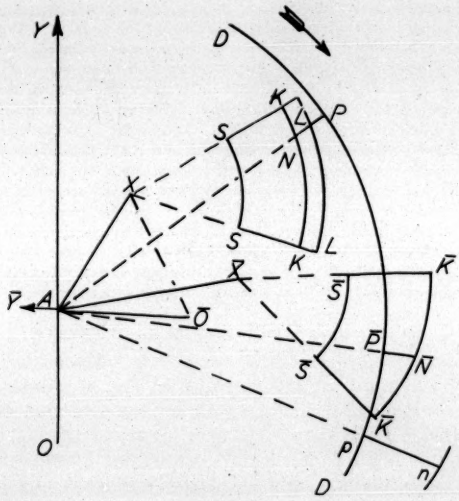

FIG. 1.

circle; it must be considered in general as arc of a curve. Let X be the normal position of the brake shoe axis when the brake is at rest, i.e., out of action, and $\bar{X}$ the position of the same axis after a rotation $\omega = \angle XO\bar{X}$. The corresponding position of the lining would be $\bar{S}\bar{S}\bar{K}\bar{K}$ if there were no drum DD. Due to the presence of the drum DD the lining is compressed and its elastic deformation z measured at $\bar{P}$ along the radius of DD is $\bar{P}\bar{N}$. Let $OA = k$, $A\bar{P} = r$ = the drum ra-

dius, $O\bar{N} = ON = u$ so that N and $\bar{N}$ represent the same point of the lining before and after the rotation ω. Let $NP = c$ be the clearance between the brake drum DD and the brake shoe lining KK when the latter is at rest. If $\angle AON = \theta$, $\angle YAN = \lambda$, from the triangles AON and $AO\bar{N}$ we have:

$$(r + z)^2 - (r - c)^2 = 2ku[\cos\theta - \cos(\theta + \omega)] \approx 2ku\omega \sin\theta;$$
$$u/(r - c) = \sin\lambda/\sin\theta,$$

because ω is very small, so that:

$$r + z \approx (r - c)[1 + 2k\omega(r - c)^{-1} \cdot \sin\lambda]^{1/2} \approx r - c + k\omega \sin\lambda,$$

therefore, c being a function of λ:

$$z \approx k\omega \sin\lambda - c(\lambda). \tag{1}$$

The clearance can be considered as a negative compression, so that for $c(\lambda)$ a formula similar to Eq. (1) holds. In order to deduce such a formula for a new brake, i.e. when the brake shoe lining is still circular in shape, call s the external radius of the lining, i.e. $s = XL$. If the brake shoe axis were at A, the clearance would be $r - s$. The brake shoe axis can be brought from its hypothetic position at A to its real position at X by a rotation $\nu = \angle A\bar{O}X$ about $\bar{O}$ (Fig. 1), so that if $A\bar{O} = X\bar{O} = k$ and $\epsilon = \angle \bar{Y}AY$,[2] we have according to Eq. (1):

$$c(\lambda) \approx r - s - k\nu \sin(\lambda + \epsilon).* \tag{2}$$

During the rotation of the brake shoe two phases of action have to be distinguished: (1) *the propagation of the contact* between the brake shoe lining and the drum and (2) a compression of the lining after the latter is in a *complete contact* with the drum. Since the effect of the wear is here studied not during a single braking but during *a whole period of working* of the brake, *the brake shoe will be considered first as continuously working, with the lining entirely in contact, the braking torque and the tangential drum velocity having adequate average constant values. After a certain time of working under these conditions, the brake shoe will be brought out of action and*

[2] $\bar{O}A\bar{Y}$, Fig. 1, is a straight line.

* This equation may be derived also directly in the same way as the eq. (1).

then put again into contact with the drum, in order that the effect of the whole previous wear can be studied during the propagation of contact. A brake works actually under variable torque and velocity, and the range of these two quantities is in general different in each single braking. But, since the subject of this study is the *total effect of the wear during a certain time of use of the brake*, the assumption of a constant torque and a constant velocity is a reasonable one.

Let dc be the increment of the clearance at a point P due to the wear at that point during the time dt. If w is the width of the lining, E the ratio of the modulus of elasticity of the lining to its thickness, μ the friction coefficient between the lining and the drum and v the tangential velocity of the drum, the Reye's law of proportionality between the volume worn by friction and the work of the friction forces gives:

$$wr \cdot d\lambda \cdot dc = H\mu wr \cdot d\lambda \cdot Ezv \cdot dt, \quad \text{or} \quad dc = z \cdot d\tau,^{3}$$

if H is the volume worn by 1 unit of friction work and the dimensionless quantity $\tau = H\mu Evt$ is taken as the measure of the time t. By (1) we obtain from $dc = z \cdot d\tau$ the differential equation of the clearance:

$$dc/d\tau = k\omega \sin\lambda - c. \tag{3}$$

In order to have always the same braking moment M, the angle of rotation of the brake shoe ω must increase as the wear goes on; therefore ω has to be considered as a function of τ. Calling $c_0(\lambda)$ the initial clearance, given by formula (2), when $\tau = 0$, the integral of (3) is:

$$c(\lambda, \tau) = ke^{-\tau} \cdot I(\tau) \cdot \sin\lambda + e^{-\tau} \cdot c_0(\lambda), \tag{4}$$

where $I(\tau) = \int_0^\tau \omega(\tau) \cdot e^{\tau} \cdot d\tau$. The compression of the lining is therefore by (1):

$$z = k(\omega - Ie^{-\tau}) \sin\lambda - c_0(\lambda) \cdot e^{-\tau}. \tag{5}$$

Comparing (5) with (1) one can easily see that *the effect of the wear on the brakes can be accounted for as a lessening of the clearance according to the exponential law* $c_0(\lambda) \cdot e^{-\tau}$ *with a simul-*

[3] The reduction of the thickness of the lining by the wear is practically without effect on its "stiffness" E, so that E may be considered as constant. See p. 196 of the paper cited in reference 5.

taneous change of the angle of rotation of the brake shoe according to the expression $\omega(\tau) - I(\tau)\cdot e^{-\tau}$.

The expression for $\omega(\tau)$ may be deduced in the following manner: If λ_1 and λ_2 are the upper and the lower end values of λ and $n = \mu w E r^2$, the braking moment is by (1):

$$(6)\quad M = n\int_{\lambda_1}^{\lambda_2} z\cdot d\lambda = nk(\cos\lambda_1 - \cos\lambda_2)\omega - n\int_{\lambda_1}^{\lambda_2} c\cdot d\lambda.$$

By (5), M may be written also as:

$$(7)\quad M = nk(\omega - Ie^{-\tau})(\cos\lambda_1 - \cos\lambda_2) - ne^{-\tau}\int_{\lambda_1}^{\lambda_2} c_0(\lambda)\cdot d\lambda.$$

Since M, being the average braking moment, is supposed a constant, the derivative of (6) with respect to τ gives:

$$(8)\quad O = nk(\cos\lambda_1 - \cos\lambda_2)\cdot d\omega/d\tau - n\int_{\lambda_1}^{\lambda_2} dc/d\tau\cdot d\lambda.$$

But $n\int_{\lambda_1}^{\lambda_2} dc/d\tau\cdot d\lambda = n\int_{\lambda_1}^{\lambda_2} z\cdot d\lambda = M$, so that the integration of (8) with respect to τ gives:

$$(9)\qquad \omega(\tau) = \omega_0 + M[nk(\cos\lambda_1 - \cos\lambda_2)]^{-1}\tau,$$

where ω_0 is the initial value of $\omega(\tau)$, for $\tau = 0$, which by (6) and (2) is:

$$\omega_0 = \{M + n(r-s)(\lambda_2 - \lambda_1) + nkv[\cos(\lambda_2+\epsilon) - \cos(\lambda_1+\epsilon)]\}\cdot[nk(\cos\lambda_1 - \cos\lambda_2)]^{-1}.$$

Eq. (9) means that *in order to obtain the same braking moment irrespective of the wear of the lining, the angle of rotation of the brake shoe must increase proportionally to the time of use of the brake.*

Until now the lining was supposed to be constantly in contact with the drum. Let us now study the variation of the braking moment *during the propagation of contact* after a time τ of use of the brake. The formula (6) can still be used, although M and ω are now variable; ω may be considered as an independent variable increasing from 0 to the value given by (9) (M means in Eq. 9 the average braking moment which is a constant); λ_1, λ_2 are the values of λ at the end points of contact and in general one of them only (usually λ_2, which is the end nearer to O, Fig. 1) is variable during the propagation

of contact. For each value of ω, the varying end of contact is determined as that value of λ for which $z = 0$ (Eq. 5), i.e. as the solution of the equation in λ:

$$\omega = [I + k^{-1} \csc \lambda \cdot c_0(\lambda)]e^{-\tau}. \tag{10}$$

The point where the contact starts is determined as that value λ_s of λ, for which the ω of (10) is minimum. (10) proves that λ_s is independent of τ, so that *the first contact between the lining and the drum occurs always at the same point, irrespective of the change of the lining in consequence of the wear.*

The angle of rotation of the brake shoe from the beginning to the end of propagation of contact is by (10):

$$[\csc \lambda_e \cdot c_0(\lambda_e) - \csc \lambda_s \cdot c_0(\lambda_s)]e^{-\tau}/k, \tag{11}$$

λ_s being the value of λ where the contact propagation starts and λ_e where it ends. Usually $\lambda_s = \lambda_1$ and $\lambda_e = \lambda_2$.* The

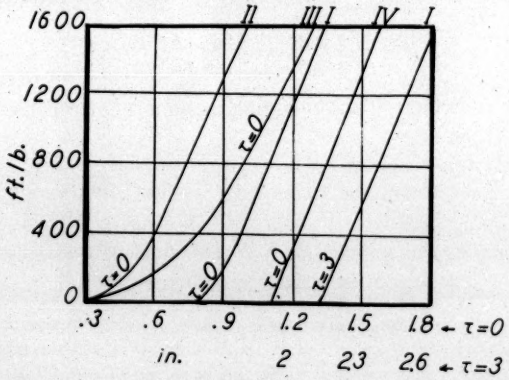

FIG. 2.

formulas (7) and (10) enable one to plot the braking moment against the angle of rotation of the brake shoe or against the stroke of the brake pedal (Fig. 2). When the whole lining is in contact the graph is a straight line, because in (6) λ_1 and

* i.e. $\lambda_s < \lambda_e$, because it is assumed throughout this paper that the subscripts 1 and 2 are chosen in such a manner that $\lambda_1 < \lambda_2$.

λ_2 are constants. During the propagation of the contact the graph is a curve; depending upon its shape the braking action is an abrupt or a progressive one. The braking moment, when the propagation of contact is completed ($\lambda_e = \lambda_2$), is:

$$(12) \quad n\left[c_0(\lambda_2)\cdot \csc \lambda_2 \cdot (\cos \lambda_1 - \cos \lambda_2) - \int_{\lambda_1}^{\lambda_2} c_0(\lambda)\cdot d\lambda\right] e^{-\tau}.$$

This formula is obtained from (7) eliminating ω by means of (10) where $\lambda = \lambda_2$. It is seen from (11) and (12) that *the duration of propagation of contact between the lining and the drum,* as well as the braking moment reached just when the contact is completed, decrease exponentially with the time of use of the brake.* This means that the curved part of the graph of the braking moment (Fig. 2) becomes smaller and smaller as the wear goes on and consequently the action of the brake becomes more and more abrupt.

In Fig. 2 graphs for an automobile brake with 8 equal and equally acting brake shoes are drawn: $r = s = 5''$, $k = 4''$, $w = 1.5''$, $\mu = 0.3$, $E = 20{,}000$ lb./cu. in., $H = 0.009$ cu. in./HP.hour, $v = 11$ ft./sec., $\lambda_1 = 55°$, $\lambda_2 = 165°$. These values involve the following relation between the time t and its dimensionless measure: $\tau = 1.2\ t$ hour^{-1}. The total average braking moment is assumed = 1400 ft. lb., i.e. 175 ft. lb., per brake shoe. In Fig. 2 the braking moment of all the 8 brakes is plotted against the stroke of the pedal which is assumed to act on the brake shoe with a transmission ratio = 36. The Table contains some characteristics of the different brake shoe adjustments, to which the graphs Fig. 2 refer. The arrangement I is that recommended by the manufacturer. $\tau = 0$ means a new circular shaped lining, $\tau = 3$ represents the conditions of the brake after $t = \tau/h = 3/1.2 = 2.5$ hours of continuous working. At that time the whole graph I is practically reduced to a straight line, which means an abrupt action of the brake.§ The arrangement IV gives a similar graph even for $\tau = 0$. With the arrangement III the braking action is very progressive, but the propagation of

* The angle (11) is taken as the measure of the duration of propagation of contact.

§ The limitations of the stroke of the brake control organs prevent an automobile brake from reaching such state of action.

contact is so slow that an extremely large moment results from the complete contact (see the Table); this means that only part of the lining can be used. The same trouble arises, although to a lesser degree, with the arrangement II. The arrangement I appears as a compromise between the progressiveness of action and the possibility of utilization of the whole lining.

The previous formulas enable one to answer the question about the effect of the wear on the self-locking of the brake-shoes. A brake shoe is self-locking if the resultant of the radial and the friction forces acting on the brake shoe tends to drive it in the direction of increasing friction moment. Therefore, assuming that the contact propagation starts at the upper end λ_1, it is easy to see that the condition for non-self-locking of the brake shoe is that for all values of $\lambda > \lambda_1$:

$$(13) \qquad n\int_{\lambda_1}^{\lambda}[\mu(\tau + k\cos\lambda) - k\sin\lambda]z\cdot d\lambda < 0.$$

Let λ_0 be a value of λ for which $[\cdots]$ in (13) vanishes. Such a value lies between 0 and 90° because $[\cdots]$ is positive for $\lambda = 0$ and negative for $\lambda = 90°$. Since nz is positive, the condition (13) is satisfied for all $\lambda > \lambda_1$ only if $\lambda_1 > \lambda_0$. The relation $\lambda_1 > \lambda_0$ is therefore the *condition for non-self-locking*. λ_0 is independent of the τ, so that *the self-locking of a brake-shoe is independent of its wear.*

TABLE

Braking moment for various brake shoe arrangements (I, II, III, IV) with new ($\tau = 0$) and with worn out ($\tau = 3$) brake shoe linings.

Brake Shoe Arrangement and Value of τ		Initial Clearance (in.).		Pedal Stroke (in.) from the Beginning to the End of Propagation of Contact.	Total Braking Moment (ft. lb.) When the Propagation of Contact is Completed.
		$c_0(\lambda_1)$.	$c_0(\lambda_2)$.		
I	$\tau=0$	.009	.004	.3	790
I	$\tau=3$	.009	.004	.016	40
II	$\tau=0$	.004	.004	.7	1850
III	$\tau=0$	.004	.009	2	5250
IV	$\tau=0$	.013	.004	.003	20

CONCLUSIONS.

The purpose of this theory was to explain some fundamental facts concerning the working of the brakes. For simplicity of treatment the object of the study was limited to a single brake shoe, but the method used may be easily extended to combinations of brake shoes as they actually occur in applications.*. Some simplifying hypotheses of physical and mathematical nature were introduced: the first consisted in neglecting the elastic deformation and the wear of the drum, the second will be made clear by the following Appendix in which a more refined mathematical approach is outlined.

APPENDIX.

Since the properties of the brake depend on the brake shoe lining, they may be considered as functions of the brake shoe lining surface and are therefore *functionals* of that surface. The functional analysis[4] makes it possible to study the effect of the wear without the approximations introduced in the main text of this paper.

Consider the brake shoe lining in braking position after a time t of use of the brake and let $\overline{K}\overline{K}$ be the corresponding position of the external surface of the brake shoe lining, if there were no cylinder DD. During the infinitesimal interval of time between t and $t + dt$ the brake shoe must rotate about O by a certain angle $d\omega$ in order to satisfy the condition of constant braking moment. If there were no wear during dt, then—removing the cylinder DD at the instant $t + dt$—we would find $\overline{N}$ at n if $\angle \overline{N}On = d\omega$ and $O\overline{N} = On$, so that the elastic deformation at p at the instant $t + dt$ would be $pn = z + \partial z$, where ∂z is the increment of $z = \overline{P}\overline{N}$ due to the rotation $d\omega$ of the brake shoe. Actually the lining has been worn during dt, let dl be the variation of its thickness measured along the radius Ap in consequence of this wear (dl is <0). Then the actual *elastic* deformation of the lining at the instant $t + dt$ is: $z + \partial z + dl$. If $\angle YA\overline{N} = \zeta$,

* Cf. reference 5, pp. 167–168.

[4] For fundamental concepts of functional analysis the reader is referred to G. C. Evans, "Functionals and Their Applications," *American Mathem. Soc. Colloquium Lectures*, vol. V, part I, pp. 1–2 and 52–54.

then $\angle YAn = \zeta + d\zeta$. If $\angle AO\bar{N} = \vartheta$, $\angle AOn = \vartheta + d\omega$, $O\bar{N} = On = u$, $OA = k$, $AP = Ap = r$, we have from triangle OAn:

$$(14) \qquad (r + z + \partial z)^2 = k^2 + u^2 - 2ku \cdot \cos(\vartheta + d\omega).$$

Putting here $\cos(\vartheta + d\omega) = \cos\vartheta - \sin\vartheta \cdot d\omega$ and introducing the following relations which may be obtained from triangle $OA\bar{N}$:

$$u^2 = k^2 + (r + z)^2 + 2k(r + z)\cos\zeta,$$
$$k = u\cos\vartheta - (r + z)\cos\zeta,$$

the finite terms of (14) vanish and the differentials of the first order give: $(r + z) \cdot \partial z = ku \sin\vartheta \cdot d\omega$. Since $u \sin\vartheta = (r + z)\sin\zeta$ we get: $\partial z = k \sin\zeta \cdot d\omega$, so that the total variation of the elastic deformation z during dt is:

$$(15) \qquad dz = k \sin\zeta \cdot d\omega + dl.$$

dl may be calculated from the Reye's law of wear:

$$(16) \qquad dl = -h \cdot (z/l) \cdot dt,$$

where

$$h = H\mu E_c v.$$

E_c means the modulus of elasticity of the brake shoe lining. From $\Delta OA\bar{N}$ and OAn we have:

$$u^2 = k^2 + (r + z)^2 + 2k(r + z)\cos\zeta$$
$$= k^2 + (r + z + \partial z)^2 + 2k(r + z + \partial z)\cos(\zeta + d\zeta).$$

Putting $\cos(\zeta + d\zeta) = \cos\zeta - \sin\zeta \cdot d\zeta + \cdots$ and neglecting the differentials of higher orders, we get: $[k\cos\zeta + (r + z)] \cdot \partial z = k(r + z)\sin\zeta \cdot d\zeta$. Remembering now that $\partial z = k \sin\zeta \cdot d\omega$ we reach the relation:

$$(17) \qquad (k\cos\zeta + r + z) \cdot d\omega = (r + z) \cdot d\zeta.$$

In the previous formulas ζ has been considered as a function of ω, i.e. of t only, and the corresponding differential has been called $d\zeta$. Let us now consider ζ as a function of the point on DD only, and call $\delta\zeta$ the corresponding differential. The moment of the friction forces about A is then:

$$(18) \qquad M = \mu w r^2 E_c \int_{\zeta_1(1)}^{\zeta_2(1)} (z/l) \cdot \delta\zeta,$$

where $\zeta_1(t)$ and $\zeta_2(t)$ mean the values of ζ corresponding to the ends of the lining and are functions of t. On the other hand, from (15), (16) and (17) we get:

$$(19) \qquad \frac{dz}{dt} = k\frac{d\omega}{dt}\sin\zeta - h\frac{z}{l}, \quad \frac{dl}{dt} = -h\frac{z}{l}, \quad \frac{d\zeta}{d\omega} = 1 + \frac{k\cos\zeta}{r+z}.$$

The problem is in this way reduced to the determination of the functions:

$$(20) \qquad z(\zeta, t); \quad l(\zeta, t); \quad \zeta(t); \quad \omega(t),$$

satisfying the integro-differential system (19), (18) with the initial conditions:

$$(21) \qquad \omega(0) = \omega_0; \quad z(\zeta_0, 0) = z_0(\zeta_0); \quad l(\zeta_0, 0) = l_0,$$

where

$$\zeta_0 = \zeta(0).$$

$z_0(\zeta_0)$ means the compression of the lining when new ($t = 0$), l_0 being its thickness and $\omega = \omega_0$ the brake shoe rotation.

If we consider ζ as a function of t and ζ_0, i.e. $\zeta = \zeta(\zeta_0, t)$, and introduce this expression in (20), we get z and l as functions of ζ_0 and t, i.e.: $z = z(\zeta_0, t)$; $l = l(\zeta_0, t)$, so that the integral equation (18) may be written:

$$(22) \qquad \int_{\zeta_1(0)}^{\zeta_2(0)} \frac{z}{l} \cdot \frac{\partial\zeta}{\partial\zeta_0} \cdot d\zeta_0 = \frac{M}{\mu w r^2 E_c}.$$

The system (19), (22) may be solved by successive approximations[4] starting for instance from the initial values (21). Or, $z(\zeta_0, t)$; $l(\zeta_0, t)$; $\omega(t)$ may be expanded in power series of t and the coefficients of such expansions may be calculated by differentiating (19) and (22) with respect to t. The numerical evaluations of these expansions[5] prove that the approximations introduced in the main text give a completely sufficient degree of accuracy.

[5] I. Opatowski, *Memorie R. Accad. d. Scienze*, Torino (1938–1939), ser. 2, v. 69, part I, pp. 145–198.

Researches at Mellon Institute 1941–42.—Outstanding at Mellon Institute during the fiscal year ended February 28, 1942, has been the growth of the industrial research staff to 205 fellows (from 187) and 150 fellowship assistants (from 114). The services of these scientists and engineers have been required on the 95 industrial fellowships in operation. The investigational exigencies of the emergency have in fact caused a considerable expansion in the activities of certain fellowships, particularly those concerned with coke by-products, and have resulted in many special studies for Federal Government agencies by various fellowships, such as those pertaining to heat-insulation, petroleum, plate glass, protective coatings, synthetic organic chemicals, and tar synthetics. Of special interest is the information set forth regarding continued industrial fellowship researches. Anthrafloss is a high-grade mineral wool for insulating purposes made from anthracite by-products by the multiple fellowship of Anthracite Industries, Inc. The multiple fellowship on heat insulation and roofing has aided in the development of an efficient insulating material suitable for temperatures up to and including 1500° F. A prominent consequence of the research program of the multiple fellowship on plastic metals has been the construction of a large commercial sponge-iron plant. The activities of other fellowships have benefited gray cast-iron and steel production. Of pertinence here is the research of another fellowship on the refining of chromium. The multiple fellowship of the American Iron and Steel Institute has pursued steadily the utilization of waste pickle liquor. Research initiated by this fellowship has been conducted on five potential processes for the recovery of values from this industrial waste; the investigational work includes the recovery of free sulfuric acid and copperas, the manufacture of iron carbonate and ammonium sulfate, the production of magnesium from low-grade ores by leaching with waste pickle liquor, and the preparation of sodium sulfate and ferric chloride. In the realm of ceramics, cast-iron enameling, hollow-ware enameling materials, flat glass, and waste grinding sand from plate-glass manufacture are the projects of various fellowships.

R. H. O.

TRANSMISSION OF POWER IN COMPRESSED GAS ATMOSPHERES.

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AN EXPERIMENT IN LIBRARY RESEARCH.

Introductory Note: In an article entitled "Library-Laboratory Research" at p. 381 of the May 1941 issue of *Mechanical Engineering*, Mr. Arthur Connolly is quoted as of the opinion that often the romance of discovering Nature's secrets in the LABORATORY is preferred to the drudgery and irksomeness of LITERATURE investigation. Mr. Connolly states that LIBRARY RESEARCH usually requires but a small fraction of the outlay associated with LABORATORY RESEARCH and may result in time savings of weeks, months and even years. Not infrequently, it spares the researcher the disappointment of subsequently learning that his expensive LABORATORY RE-

SEARCH simply has led him to conclusions which, long before, had been described in the LITERATURE almost as completely as if he himself had collaborated in preparing that prior description. For these and several other convincing reasons which he sets forth, Mr. Connolly concludes that, in spite of its less attractiveness, LIBRARY RESEARCH can with advantage be employed to a much greater extent and with much greater thoroughness than now is usual, in advance of undertaking the LABORATORY work. Frequently this literature preparation will lead to a program of laboratory research which will yield a richer return for the time and talent devoted to it, than otherwise would have been the case. Sometimes the LIBRARY RESEARCH will provide much of the information for which the LABORATORY RESEARCH was to have been undertaken. In general, it will serve to eliminate wasted effort and loss of time, representing the equivalent of immense expenditures. Mr. Connolly's article concludes as follows:

> "With proper balance and coöperation between the Laboratory and the Library scientists, millions of dollars wasted annually in repeating old investigations will be saved. The stream of data continually increasing the volume of scientific literature, will be carefully searched, correlated, and efficiently utilized. Important inventions will be speedily skimmed from the literature instead of reposing unknown and unused. Our industrial research will then attain a new efficiency peak, and frontiers of knowledge will expand more rapidly than ever before, to the advantage of scientists, industry, and civilization."

The Purpose of the Present Article: This article constitutes an attempt to advance, by LIBRARY RESEARCH, interest in utilizing COMPRESSED GASES for insulating purposes as alternatives to, or in combination with, the dielectric materials now commonly employed.

Although a limited amount of LABORATORY RESEARCH in this field, already is available, and further researches are in progress, practical applications of great present value still are receiving insufficient attention because of the dearth of basic information derived from careful laboratory tests. It is hoped that this LIBRARY RESEARCH article may lead to in-

creased interest and the undertaking of much needed further LABORATORY RESEARCH on the dielectric characteristics of compressed gases.

The present writer's study of the subject of the dielectric characteristics of compressed gases has convinced him that (1) a 60-cycle underground (or surface) transmission system for very high voltage and employing compressed gas as insulation, and (2) compressed gas power transformers, will constitute two important engineering applications. Ultimately they will be widely employed for power transmission and for power pools, and will be accompanied by great economies and operating advantages.

Quite aside, however, from these two projects, it appears timely to have available in a form adapted to serve engineering purposes (as has been attempted in this article), some basic data of the insulating properties of compressed gases. The existing data of the subject is meager, often inconsistent, and widely scattered. It needed discriminative checking and coördinating in order that it may be utilized effectively by engineers.

In the course of this coördinating task, it was inevitable that the writer should learn (from the sources consulted) of many phenomena which are in need of further LABORATORY RESEARCH before (in engineering design), they can be taken into account with the degree of certainty essential to obtaining the best results. It is hoped that scientists may become sufficiently interested to undertake these needed laboratory researches, whose general nature is indicated at various parts of this report. If that is done, then, irrespective of whether the results reveal faults or advantages, the way will be cleared for many useful new applications of compressed gases in various kinds of machinery, not only on account of their insulating properties, but also for heat-transfer and other purposes. Probably most of these new applications will be completely unrelated to the particular projects now being investigated by the present writer.

Fundamental Dielectric Data of Compressed Gases: The curves in Fig. 1, show the breakdown strengths of several gases when compressed to 20 and 40 absolute atmospheres (ata), for sine-wave voltages of usual periodicities (50 and 60

cycles). The ordinates are crest volts per mil and the abscissæ are spacings in mils. The electrodes employed were of such shapes and dimensions as to decrease the non-uniformity of the field for the spacings employed. The curves are of the nature of composites made up from various published reports of LABORATORY RESEARCHES which bear the evidences of earnestness and skill on the part of the researchers. Comparatively few of these researches included

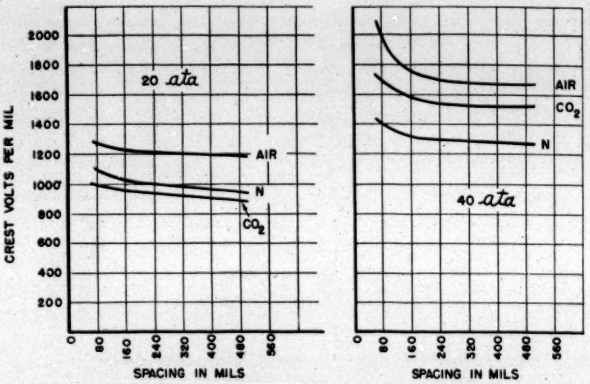

FIG. 1. Crest breakdown strength of air, nitrogen and CO_2.

simultaneously, high compressions, great spacings, and very high voltages.

Although there were many unaccountable and often considerable differences in the results examined, these composite curves are reasonably adequate to serve as bases for the engineering-estimate purposes of the present article.

As only one out of the many examples which could be cited with respect to the inevitableness of considerable deviations due to the particular conditions applying to each research, it is of interest to quote from a statement by Dr. J. G. Trump, published at p. 676 of Vol. 60 (1941) of the *A. I. E. E. Transactions* (see June 1941 "Supplement to Electrical Engineering Transactions Section"), as follows:

"We have observed that the maximum voltage which can be readily obtained under given conditions of pressure and field geometry, is less when the area of the electrodes is large. This is probably caused by the increased difficulty of approaching ideal conditions over large areas. It may be estimated that the effective area of our inter-electrode gap was about a hundred times that of Prof. Skilling. Considerations such as these must be taken into account by engineers interested in applying to large apparatus, high-voltage data taken on small electrodes."

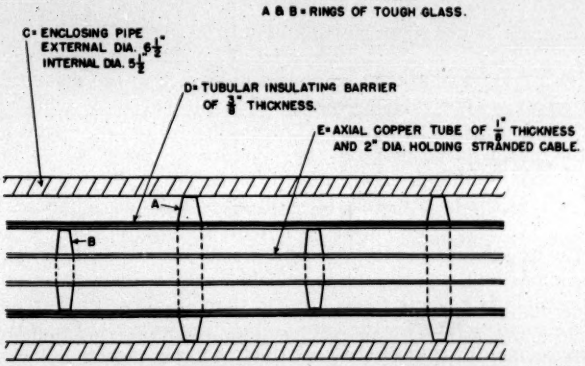
A & B = RINGS OF TOUGH GLASS.
C = ENCLOSING PIPE
EXTERNAL DIA. 6½"
INTERNAL DIA. 5½"
D = TUBULAR INSULATING BARRIER
OF ⅜" THICKNESS.
E = AXIAL COPPER TUBE OF 1" THICKNESS
AND 2" DIA. HOLDING STRANDED CABLE.
A
B

FIG. 2. High voltage, pipe-enclosed, underground conductor with compressed gas insulation. This sketch is simply diagrammatic and is not to scale.

In continuation of the above-quoted text, Dr. Trump alludes to many other extremely complicated factors involved in breakdown tests of gases. Indeed, his entire statement about this aspect of the subject, should be studied with care by engineers concerned with applying to practical use the dielectric properties of compressed gases.

Compressed-gas-insulated, Pipe-enclosed, High-voltage, Conductor: The diagrammatic sketch in Fig. 2, relates to a proposed design for conductor and insulation, for a three-phase, compressed-gas, 60-cycle transmission line with a SYSTEM voltage of 345,000 volts, the PHASE voltage consequently being

200,000 volts. Between the inner surface of the enclosing pipe C and the outer surface of the axial copper tube E (which may alone constitute the conductor, or may be reënforced by containing a stranded conductor), the stress in service corresponds to the phase voltage of 200,000 r.m.s. volts or 283,000 crest volts. The radial spacing between the 2″-diameter conductor E and the enclosing pipe C is $1\frac{3}{4}$″. Thus the AVERAGE gradient for the entire gap is (283,000/1750 =) 162 crest volts per mil. Later in this article, it will be shown that the voltage-stress AT THE SURFACE of the conductor E, is, in service, 280 crest volts per mil, and we must provide a gas and a degree of compression which will correspond to a suitable factor of safety when withstanding this stress.

Voltage stresses of this order of magnitude are already (in a few installations) employed in service in the insulating wall of a type of high-voltage underground cable which is provided with a filling of thin, degasified oil for impregnating the paper insulation on the conductor. Such cables are provided with external means for maintaining the oil under a low pressure of the order of 15 to 25 pounds per square inch to prevent void formation within the confines of the sheath. The original of this type of cable was devised in Italy by the firm of Pirelli. Although these cables are excellent, their cost per mile is several times greater than the cost of *overhead* transmission lines for the same voltage and power. Their use, consequently, is limited to relatively short distances, and for locations where *overhead* lines would not be permitted. The highest voltage for which such cable has yet been employed, corresponds to a SYSTEM voltage of 220,000 volts and a PHASE voltage of 127,000 volts.

The example of a 345,000-volt line (corresponding to the dimensions on the sketch in Fig. 2), was purposely taken for illustrating the system described in this article, since while 345,000 volts is believed to be much lower than voltages attainable with a compressed gas design of the kind which will be described, it is well above present proven practice, not only for underground cables but for overhead transmission lines. It is more interesting and helpful to establish a sound case for what has not yet been done (although admittedly

desirable to be done) than to make a proposal which will be merely an alternative to ways at present employed.

It is, however, believed that the proposed high-voltage, compressed-gas, 60-cycle system is not only of superior value for the transmission of large amounts of power to great distances, but that it will be of *lower cost* than *overhead* transmission lines of equal reliability, and will be much cheaper than any *underground* high-voltage system at present available. If exclusively used for an entire high-voltage system, immunity is secured from lightning damage and lightning outages. If it is applied to *extending present* OVERHEAD lines (which evidently must be the usual case for some time), the system has features which permit of providing adequate surge attenuation before the arrival of the lightning transient at the step-down compressed-gas transformers. These step-down transformers will be entered through pipes containing COMPRESSED GAS instead of through the expensive, and by no means invulnerable high-voltage, oil-type, bushings at present employed.

It is admitted that there still is but meager knowledge of the dielectric properties and propensities of compressed gases, and it is urged that much more fundamental research on the subject be promptly and vigorously undertaken. If these further investigations show the need for a greater radial gas spacing than that indicated in Fig. 2, such greater spacing will be employed and vice-versa. Comparatively simple tests with short lengths of pipe would be very useful in fixing ideas of the suitable dimensions.

It should be noted that this project will make available an economical 60-cycle high-voltage power-transmission system which is not dependent upon conspicuous and vulnerable OVERHEAD lines. All parts of the system (including the compressed-gas power-transformers), may be located underground. This is only one of the several important features of the system, but its bearing upon the NATIONAL DEFENSE is particularly evident at the present juncture and justifies a modest outlay for the research and experimentation desired.

Preliminary Application Tests of this System Should not Await Completion of Fundamental Researches: Notwithstanding the present insufficiency of our knowledge in the field under

consideration (use of compressed gas as insulation), it is believed that with careful liberality in the proportioning of the parts required, we already know enough of the subject to justify going ahead vigorously with an actual trial design which should be placed in service as a branch or extension of some already-existing system. If such an experimental branch line is shown to be satisfactory (and this should be capable of demonstration in a reasonably short time), and if the superiority in performance, and the saving in cost are as great as has appeared from careful study to be quite certain to be the case, it is only reasonable to anticipate the wide use of the system in the contemplated early expansion of the NATION'S electric power facilities.

The Pipe-enclosed Conductor: Let us now return to the consideration of the sketch in Fig. 2. The enclosing pipe will be of suitable material and strength. The method of supporting the conductor will be described in a later part of this article.

Finkelmann's Researches on Compressed-gas Dielectrics: Some researches reported by Finkelmann at pp. 282 to 286 of Vol. XXXI (1937), of "Archiv für Elektrotechnik," included measurements of the breakdown strength of several gases for the very non-uniform field conditions between concentric-cylindrical electrodes, as compared with their breakdown strengths between parallel-plate electrodes, providing a fairly uniform field. In the case of the concentric-cylindrical electrodes, the inner diameter of the outer cylinder was about 8″ (d_1 = 8000 mils). Tests were made with four inner cylinders whose outer diameters were respectively about 7200, 6400, 5600 and 4800 mils. The corresponding spacings thus were about 400, 800, 1200 and 1600 mils. The largest of these spacings (1600 mils) is seen to be not much different from the design in Fig. 2 (where the spacing is 1750 mils). But Finkelmann's inner cylinder for that spacing was of about 4800 mils outer diameter, whereas the outer diameter of the conductor in Fig. 2, is only 2000 mils. This difference prevents drawing more than very rough conclusions.

There now will be undertaken a comparison between these two sets of conditions, with the object of seeing whether and to what extent the test results from Finkelmann's research

can contribute helpful (although only rough) guidance for our compressed-gas, pipe-enclosed, transmission-line project. An additional difference between Finkelmann's condition and ours, relates to the use of a much higher compression (50 ata) in the case sketched in Fig. 2, instead of the compressions extending up to only half that amount, used in Finkelmann's research. No alternating-voltage test results for the dielectric strength of CO_2 gas at as high a compression as 50 ata, associated with so great a spacing as 1750 mils and between concentric cylinders, appear to be available.

The curves in Fig. 3, for concentric-cylinder gaps, represent the next step in our library research. The 10 ata and the 20 ata curves are obtained quite directly from the data in the Finkelmann publication. By reasonable extrapolation and from analogy with other available data, the 30 ata and 50 ata curves (at the right-hand side of Fig. 3), have been constructed.

In the curves of both Fig. 1 and Fig. 3, interest attaches to the great changes in the relative shapes and values for the different gases. The curves must be regarded as based simply on empirical data for which the "reasons-why" are not yet known. It will take a great amount of earnest further research to provide the desired important enlightenment. On the basis of the data at present available, Fig. 2 appears to represent a reasonable basis for consideration. The project presents such great advantages as to justify a pipe design employing a considerably greater diameter and, consequently greater cost, if further investigations show it to be desirable.

The curves in Figs. 1 and 3 show us that both for plane gaps and for concentric-cylinder gaps, nitrogen becomes increasingly inferior to the other gases examined, the greater the compression employed, and that for large spacings in the concentric-cylinder tests, nitrogen shows up particularly badly. Thus we are tempted to turn our attention to alternatives, such as air and carbon dioxide.

Zeier's Researches on the Dielectric Properties of Compressed Gases: An interesting comparison between the dielectric strengths of AIR and NITROGEN is found in a test made by Zeier ("Annalen der Physik," **14**, p. 433, 1932). At a compression of 40 ata, and employing a 20-mil spacing between

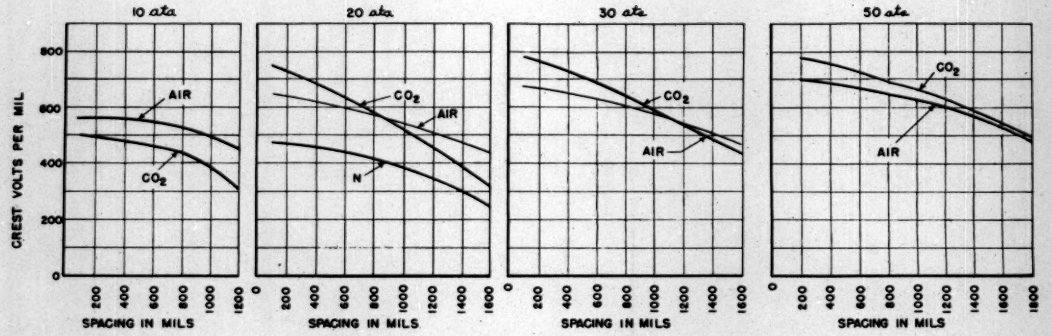

FIG. 3. Dielectric strength for various spacings and compressions of air, nitrogen and CO_2, in fields between concentric cylinders.

two spheres of 15 mm. diameter, Zeier measured the breakdown voltage for pure nitrogen gas. Then Zeier gradually replaced the nitrogen by air, measuring the breakdown voltage at each increase in the amount of air. For 100 per cent. air, the dielectric strength was about 18.5 per cent. greater than for 100 per cent. nitrogen. Zeier furthermore noted the important phenomenon of a gradual decrease in the "spread" or "scatter" in the observed values with increasing proportions of air. If we neglect the fact of the presence in air of small amounts of other gases (which may amount to about 2 per cent.), and simply consider its nitrogen and oxygen content, we must attribute to the 21 per cent. of oxygen corresponding to the "all air" condition, the great increase in the dielectric strength as compared with "all nitrogen." The tests were made with direct current and the results are tabulated below.

Notes.	Nitrogen.	Oxygen.	D.C. Breakdown Voltage.	Crest, Volts per Mil.	"Spread" in Observed Values.
All Nitrogen	100%	0	49,000	2,440	4.5%
	95%	5%	53,800	2,690	1.7%
	90%	10%	55,000	2,750	1.4%
	85%	15%	56,500	2,830	1.1%
	80%	20%	57,500	2,880	0.8%
All Air	79%	21%	58,000	2,900	0.7%

The "spread" in the values observed for the breakdown voltage, is an important factor in judging of the dielectric suitability of a gas. It is interesting to notice that in the Zeier test, the addition to the nitrogen of only a few per cent. of oxygen, halved the "spread." It is well known that at atmospheric pressure, the presence of an exceedingly small quantity of CCl_4 vapor in air, *doubles* its dielectric strength. Thus it appears that in gases, just as in solid and liquid materials, there are evidences that the merest trace of some foreign substance may exert an utterly disproportionate influence on some important property of a gas. Facts of these kinds indicate that careful study should be given to the possibilities of greatly improving the dielectric properties of gases by adding small but appropriate foreign ingredients. Similarly, the removal of even very slight quantities of an

undesirable ingredient, reasonably may be expected to effect well-worth-while improvements. Some researchers have observed that very slight impurities in electrode materials, and even mere surface contaminations of the electrodes, have exerted surprising effects on the values obtained for the breakdown voltages.

Some Tests with Different Electrode Materials: At p. 114 of the March, 1941 issue of *Transactions A. I. E. E.*, Skilling and Brenner report results obtained by them for the breakdown strength of air with spacings of 50 mils and less, and a compression of 20 ata, between brass and steel spheres. With the steel spheres, the breakdown strengths were some 10 per cent. to 15 per cent. greater than with the brass spheres. Goldman (p. 91 of *Comptes Rendus de l'Academie des Sciences de l'U.R.S.S.*, 1938, Vol. XVIII, No. 2), investigating the breakdown strength of nitrogen over a wide range of compressions, found that for a spacing of 0.4 mil between a 20 mm. diameter steel sphere and a 50 mm. diameter flat disc, the 50-cycle breakdown voltages were 8 per cent. to 10 per cent. higher with a chemically-pure aluminum disc than with a brass disc. It would be helpful to have results of tests with the gas passing through the gap at various speeds to see whether these results are affected by the speed.

Comments on Air, CO_2, and Nitrogen: Finkelmann cites as disadvantages of air, (1) "the danger of ozone formation" and (2) "the precipitation of deposits on the electrodes," which suggests a proneness to electrode-surface contamination. With regard to CO_2, Finkelmann states that "it should be noted that CO_2 may be more readily obtained free from dust particles and traces of moisture than is the case with nitrogen." He continues by stating that the "scatter" of the values of the breakdown voltages is far less for CO_2 than for nitrogen. In this respect of the considerable "scatter" of the breakdown values in nitrogen, we thus find agreement with Zeier.

Taking advantage of these opinions in our LIBRARY RESEARCH, the next steps in the comparison between plane and concentric-cylindrical electrodes, are limited to CO_2. In Fig. 4, the three upper curves represent compressions of 30, 40, and 50 ata and moderately uniform fields, such as the

fields between spherical electrodes of large diameter as compared with the spacing. The three curves (and particularly the 50 ata curve), are in part plotted from values estimated by extrapolation from tests at lower compressions. There have, however, been taken into account, some LABORATORY RESEARCH results published by Zeier in 1932 for CO_2, small spacings, and 50 ata compression. The uppermost curve in Fig. 4, which is for CO_2 at 50 ata, is believed to be amply correct for use in the engineering applications with which this LIBRARY RESEARCH is concerned.

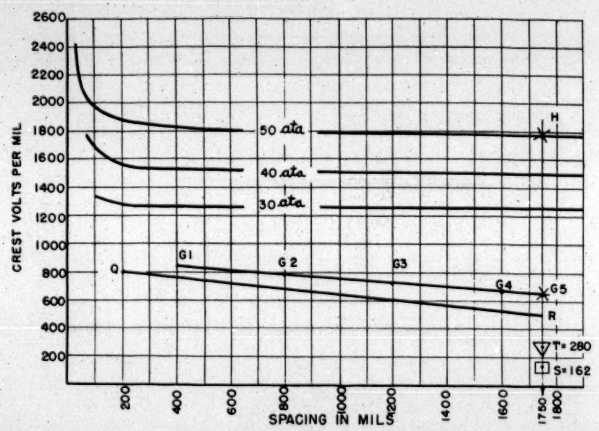

FIG. 4. Dielectric strength of CO_2 gas for various spacings and compressions. In uniform and non-uniform fields.

The Gradient at the Conductor Surface: In Fig. 4, the line *QR* for the AVERAGE breakdown strength in crest volts per mil at 50 ata for concentric-cylindrical electrodes, is similarly deduced (i.e., from the curves of Fig. 3). The values designated *G*1 to *G*4 are obtained in each case by adding to the *QR* values, the gradients at the surfaces of Finkelmann's four inner cylinders for the four corresponding spacings of 400, 800, 1200, and 1600 mils. These are the spacings which were employed by Finkelmann in his LABORATORY RESEARCH on

concentric cylinders, but with much lower compressions. The four surface-gradient values, $G1$ to $G4$, thus calculated, are: 810, 771, 720, and 677 crest volts per mil. They provide a line passing through the points $G1$ to $G4$. These G points represent the breakdown crest volts per mil at the conductor surface for the four sets of Finkelmann electrodes, which would have been observed if the CO_2 tests had been made at a pressure of 50 ata instead of at the much lower pressures used in his laboratory research.

Examination of Fig. 4, indicates that in the relatively non-uniform gap between two concentric-cylinder electrodes, the compressed gas breaks down at much lower AVERAGE stresses (expressed in crest volts per mil) than in a gap of the same spacing, between plane electrodes. Furthermore, it appears that the conductor-surface curvature accounted for but a small part of the decrease in the breakdown voltages below the values corresponding to the relatively much more uniform conditions in gaps between plane electrodes.

To what cause or causes are we to ascribe the large remainder of the total decrease (which is of the order of considerably more than 2 to 1)? Some of the decrease is due to the considerable departure from field uniformity inherent to the case of gaps between concentric cylinders. Probably a part is due to the effect observed by Dr. Trump corresponding to the relatively-much-greater electrode surfaces in the concentric-cylinder tests than in the plane-electrode tests. Possibly there was a lack of perfect symmetry in their geometry or in the geometry of their precise relative positions. It has been observed by many researchers in this field, that *surface roughness* or *surface contaminations* may exert a surprisingly great influence on the breakdown voltage. The publication does not mention the shapes employed at the two ends of the opposing electrode surfaces for avoiding stress concentrations at these ends. It is, however, only fair to the researcher to assume that careful attention was given to these various factors. As already stated, it has been explained by Dr. Trump and others, that in electronic tests of this kind, a great number of extremely complicated phenomena are involved. Indeed, the numerous complicated aspects of the subject, certainly are far too important to be lightly passed

over, and there is quoted below, the remainder of Dr. Trump's very interesting statement published in the June 1941 "Supplement to Electrical Engineering Transactions Section," as follows:

> "While the physical understanding of the breakdown mechanism in gases at high pressure, is closer to the truth now than it ever was, it seems to me that attempts to describe accurately this complicated breakdown phenomenon in terms of the physical contents of the gas and electrode system, must of necessity neglect many of the influential breakdown factors. The situation in a gas-filled gap at the moment when conditions are ripe for a cumulative discharge, is remarkable for its complexity. There are present a statistical number of molecules in various states of excitation and ionization, with many ion-producing mechanisms contributing to this condition. The gas itself has many physical properties which affect the process, and indeed the gas is usually a complex mixture of different molecules. Recombination is constantly taking place with low probability in the gas, with enhanced probability at the electrode surfaces. The electrodes are contributing to the discharge by photo-electric emission, by secondary emission due to positive-ion bombardment, and by high field-emission. These mechanisms have been quantitatively examined separately, by careful physical research in high vacuum with thoroughly out-gassed electrodes. In a gas-filled gap these mechanisms are taking place together. The electrode surface is covered by many molecular layers of contaminated material which obscure the emission characteristics of the metal itself. The electric field which may be uniform or of some other geometry because of the shape of the electrodes, is profoundly affected by both the general space charge in the gap as a whole and by the dynamic localized space charge concentration in the region of electron avalanches. The gap is being irradiated by radiations from natural radio-active materials and by cosmic rays. In spite of this complexity, it is possible and desirable, to understand the rôle which

the various processes play in the general picture of breakdown and many valuable contributions to this phase of the insulation problem have been and are being made."

Stress Concentrations in Gaseous Dielectrics: A study of the above quotation leads the engineer to recognize in particular, an important fundamental property of gaseous dielectrics, which is not present in nearly as intense degree in liquid or solid dielectrics. This relates to the great electronic mobility of gases. Microseconds are sufficient, in the case of gases, for electronic stress concentrations to shift their location and also to greatly change their intensity.

Dependence of Breakdown Voltage on Gas Mobility: At a couple of places in Zeier's research report entitled "Durchschlaguntersuchungen in Komprimierten Gasen und in Flüssiger Kohlensäure" (*Annalen der Physik*, **14**, 1932, pp. 415 to 447), allusion is made to the influence of gas mobility and the possibility of increasing the dielectric strength by circulating the gas instead of letting it remain stationary. Reasons are given why this might be effective, and references are made (in support of this proposition), to trends noticed in certain researches.

If the breakdown voltage can be increased by circulation of the gas, it should be given consideration for our pipe-enclosed, compressed-gas, power-transmission system. It will also provide an alternative means of obtaining automatic control of the temperature of the gas (a matter which is discussed later in this article when considering ways for preventing condensation when certain vapors are employed).

Zeier's article also contains allusions to the fault of particular gases (nitrogen especially) of experiencing a decrease in dielectric strength with increasing compression as the result of the attendant decreased mobility. Zeier points out that any cause (such as increase in the compression), which decreases the mobility, tends to lower the rate of increase of the breakdown voltage. Adequate circulation of the gas, conceivably may much more than restore the decrease in mobility occasioned by the increased compression. The results of LABORATORY RESEARCH on this subject would be very interesting. A research in this field which might lead to particularly

enlightening results would consist in circulating a gas maintained at some constant pressure (say 50 ata), successively at speeds of 200, 400, 800, and 1600 feet per minute, to ascertain the amount of the increase (if any) in its breakdown voltage, with increasing speed of circulation. It might, for example, be learned that a compression of 40 ata, at some high speed of circulation, would provide as high a dielectric strength as 50 ata associated with a considerably lower speed. It would appear that the effect may be greater with impulse stresses, and also that it may be greater the greater the NON-UNIFORMITY of the field.

Need for More Laboratory Research on the Phenomena of Dielectric Breakdown in Compressed Gases: Concerning many of the phenomena summarized by Dr. Trump in the statements which have been quoted in this article, there is, admittedly, utterly inadequate knowledge. The researches necessary to satisfactorily clarify the situation, will require much time and effort. Hence if engineers await the completion of, or very considerable progress with, researches which will greatly advance our knowledge in these matters, we must refrain from applying many valuable principles which certainly will serve ultimately to promote the advancement and happiness of the human race. Many important engineering achievements have, in the past, been successfully carried out, notwithstanding an equally serious insufficiency of fundamental knowledge of underlying principles. Reasonable caution and common sense have been good allies in the past, and can be also in this undertaking.

Under the circumstances of the NATIONAL EMERGENCY, we certainly should not hesitate to adopt the course of proceeding to apply to the undertaking, without further delay, such knowledge as we have already acquired. But we must not fail to keep right in the front of our minds the fact of our present condition of deplorable ignorance, and strive our uttermost to learn, just as soon as we possibly can, the "reasons-why" of all the many complicated phenomena involved. Pending the acquirement of the desired additional knowledge, we shall employ much greater factors of ignorance than the facts, when known, may show us to have been necessary. Some of us whose training and experience (such

as they may be), have been with quite other subjects than electronic phenomena, must be content to gratefully accept the help of the electronicists, and lean largely on their opinions and advice.

Returning to the consideration of the curves in Fig. 4, the next step in our LIBRARY RESEARCH consists in extending the $G1$, $G4$-line out to a gas spacing of 1750 mils, which is the spacing shown in Fig. 2, between the outer surface of the 2″-diameter conductor and the inner surface of the enclosing pipe. Designating by $G5$ the 1750-mil point on the extension of the $G1$, $G4$ line, we obtain the result of 650 crest volts per mil for the breakdown value which would have been obtained if Finkelmann had tested a fifth concentric-cylinder assembly with d_1 = 8000 mils, d_2 (the diameter of the inner conductor) = 4500 mils, spacing = 1750 mils, and using CO_2 gas at a compression of 50 ata.

Already we have noted that in the design sketched in Fig. 2, for d_1 = 5500 mils, d_2 = 2000 mils, spacing = 1750 mils, the AVERAGE crest volts per mil for the stress with our SYSTEM voltage of 345,000 volts, corresponding to a PHASE voltage of 200,000 volts, is 162 crest volts per mil. The corresponding gradient at the conductor surface is 280 crest volts per mil.

That is to say: the surface voltage gradient for our 2″-diameter conductor inside the $5\frac{1}{2}$″ internal-diameter pipe, is, in service, 280 crest volts per mil.

If, as a rough approximation, we can properly apply the Finkelmann data to considerably different diameters for a given spacing, then, basing our estimates in other respects, on the Finkelmann research, we find that for CO_2 gas at a compression of 50 ata, and a spacing of 1750 mils, the BREAKDOWN voltage gradient at the surface of the 2″-diameter conductor shown in the sketch of Fig. 2, will be 650 crest volts per mil, corresponding to the point $G5$ in Fig. 4. This is (650/280 =) 2.32 times greater than the stress of 280 crest volts per mil to which the gas at the conductor surface will be subjected *in service* with a PHASE voltage of 200,000 r.m.s. volts between the conductor and the enclosing pipe. This ratio of 2.32 cannot be considered as more than a *rough indication*, since it is based upon tests of models whose dimensions

were very different from the dimensions of the sketch in Fig. 2.

In Fig. 4, there is denoted by H, the breakdown strength in CO_2 gas for the field between plane electrodes (which has much greater uniformity), a compression of 50 ata, and a spacing of 1750 mils. The ratio of H to $G5$ is (1780/650 =) 2.74.

As already stated, the experience of physicists tells us of many phenomena which could contribute to great decreases in the breakdown strength for a given spacing, and especially when the gap is between two concentric cylinders, in place of being between parallel-plane electrodes. In view of our ignorance of many of the phenomena involved, it is only the part of prudence to assume that high ratios of this sort will apply to our contemplated construction of a pipe line enclosing a compressed-gas-insulated concentric conductor. On the other hand, it has been observed by researchers that different gases display different degrees of propensity toward decreased strength with increasing non-uniformity of field and it has been suggested that this may, to a considerable extent, be due to differences in gas mobility as well as to other phenomena.

These roughly-estimated stresses to which the conductor may be subjected in actual service with 200,000 PHASE volts between the conductor and the enclosing pipe, are:

162 AVERAGE crest volts per mil for the whole gap, as plotted at S in Fig. 4, and:
a gradient of 280 crest volts per mil at the conductor surface, as plotted at T in Fig. 4.

S (162 crest volts per mil) = 32.5 per cent. of R.
T (280 crest volts per mil) = 43.0 per cent. of $G5$.

It is also of interest to note that the ratio of the relatively much more uniform field breakdown strength at point H in Fig. 4, to the values of S and T respectively, are:

$$H/S = 1780/162 = 11.0$$
$$H/T = 1780/280 = 6.3.$$

A hasty consideration of these ratios, for H/S and H/T, evidently would lead to dangerously optimistic conclusions.

We have seen that closer examination indicates that the actual margins of reserve dielectric strength are much less. There certainly is great need for the results of further fundamental LABORATORY RESEARCHES in this field. Obviously we cannot be certain that phenomena as yet unknown or even suspected, may require *even greater* liberality in the dimensions employed.

On the other hand, we have in reserve the employment of gases of greater dielectric strength than those as yet considered in this article, and the use of higher compressions. As may be seen from the curves in Fig. 5, for crest volts per

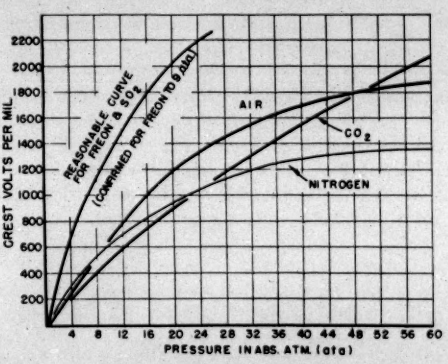

FIG. 5. 60-cycle dielectric strength of several gases for a 500-mil spacing, as a function of the compression.

mil versus compression (for a 500-mil spacing), the slope of the carbon dioxide curve is still quite steeply upward where it crosses the air curve at 50 ata. This would suggest increasing the compression of CO_2 to 60 ata, or even more, for use for insulating the pipe-enclosed conductor.

Some of the Advantages of the System: This pipe-enclosed, compressed-gas-insulated, high-voltage, 60-cycle, transmission conductor, when successfully developed, will have advantages of much importance. It will serve (and very much more effectively), the purposes for which 60-cycle, high-voltage, OVERHEAD lines are now employed. It provides

immunity from outages due to lightning storms, and from breakage of cables from accumulations on the cables of ice and sleet and by wind stresses. It decreases dangers to and from air traffic. It decreases interference with communications systems. In war time, there is less exposure to enemy depredations, and consequent outages. Power outages have occurred due to the fouling of overhead conductors by air craft. With the imminent great increase in air travel, such incidents inevitably will be more frequent. The dielectric constant of gases being unity, the use of compressed gas as insulation, will greatly decrease the capacitance, as compared with underground cables employing solid materials or oil for their insulation. This much lower capacitance will decrease the cost of providing the necessary compensation.

Cost comparisons (which necessarily must be *rough* until more experience is available), yield results which are decidedly favorable to this type of high-voltage transmission line. It will be cheaper than first-class OVERHEAD lines, and the comparison becomes rapidly more favorable to the compressed-gas, pipe-line system, the greater the amount of power per circuit, and the higher the SYSTEM voltage employed. It is precisely these conditions of greater power per circuit and higher voltages, than are practical with present methods, which will be urgently needed for really effective, large-scale expansion of the NATION'S electric power facilities.

Direct-current Transmission: Some engineers maintain that d.c. transmission will be still more effective than the 60-cycle system. Future developments are quite likely to show this to be the case. Even with present relatively inexpensive "solid filled" paper cable, the use of d.c. is practicable with insulation stresses in the dielectric, several times greater than can be withstood by such cable during years of service-subjection to 60-cycle stresses. Thus, so far as relates to the transmission line itself, the use of d.c. will permit of the *economical* provision of *underground* high-voltage transmission of large amounts of power to great distances, and of thus avoiding the many disadvantages of OVERHEAD transmission.

With the compressed-gas type, it is also true that the d.c. conditions are more economically met than are 60-cycle conditions, and careful comparisons show that the com-

pressed-gas transmission conductor's cost is, for direct-current, roughly only a matter of half its 60-cycle cost for a given high-voltage transmission application.

But taking into account as we now find them, the other factors in the d.c. versus 60-cycle high-voltage transmission situation (and particularly the vast sums already invested in 60-cycle installations), the right course at the present time, is believed by the writer to be that of building 60-cycle, long-distance and power-pool systems which will not require OVERHEAD conductors, and, among their other advantages, will not be subject to the various outages inevitable with OVERHEAD transmission lines.

Historical Note: Before concluding these considerations regarding d.c. transmission, let us again recall to our minds the late M. Réné Thury's splendid pioneering achievements in d.c. transmission using constant current instead of constant voltage. Thury's work was seriously handicapped by the sparseness of the loads in those early days, due to the slowness of the development of electrical methods and machinery. With the present enormous demands for electric power, Thury, employing practically all his original plans, certainly could have achieved great success with his system.

Making the first large-scale application to power-transmission purposes, of the developments in electronic engineering, and retaining the advantages of the constant-current feature in the transmission line, the late Mr. C. W. Stone, in the face of all kinds of discouragements, carried through to complete success, the design, construction and commercial operation of a transmission system, which, starting at Mechanicsville with three-phase, 40-cycle generated power at a constant potential of 10,500 volts, converted it to constant current by means of a Boucherot circuit, and then rectified it in phanatron tubes. The direct current, which had a constant value of 175 amperes, was then transmitted 17 miles by an overhead line to a terminal station at the Schenectady Works of the General Electric Company where it was inverted in thyratron tubes, and then converted to constant-voltage 60-cycle three-phase power in another Boucherot circuit. In that form, part of the power was used in the factories of the General Electric Company, and the rest was

delivered into the Schenectady network of the New York Power and Light Corporation. At the rated load of 5280 kilowatts, the direct-current potential was 30,000 volts.

This interesting and epoch-making transmission system was the first American example of the use, for power transmission, of direct current of constant value, and with the voltage varying with the load. The system gave entirely reliable service and some 50 million kilowatt-hours were transmitted by it in its first two years of commercial operation. The system was placed in service in August 1936, and was a fine monument to Mr. Stone's resourcefulness and indomitable determination.

Sixty-cycle Transmission: So far as regards the project described in this article, it is limited to the advocacy of the 60-cycle, pipe-enclosed, underground or ground-level, high-voltage, compressed-gas system. The OVERHEAD line typical of present high-voltage long-distance transmission practice, has extremely high first cost at 286,000 volts, the highest SYSTEM voltage yet employed. It is believed that any higher voltage with the present OVERHEAD system, will be associated with much greater first cost, and will present increased operating difficulties. But with the compressed-gas pipe-line system, studies indicate that even half-a-million volts will not constitute an upper limit, either for the line or for the step-down and step-up compressed-gas transformers which constitute an important part of the system. Engineers will thus be free to employ any voltage indicated by the economics associated with the required amount of power per circuit and the transmission distance.

(To be continued in the October issue.)

Tropopause Studies to Aid Long-Range Weather Forecasting.—(*Heating and Ventilating*, Vol. 39, No. 6.) A rising and falling of the earth's tropopause due to day-to-day variations in the heat of the sun is pictured as a possible fundamental element in world weather by DR. HENRYK ARCTOWSKI, noted Polish meteorologist now conducting investigations at the Smithsonian Institution. Dr. Charles Abbot, Secretary of Smithsonian, has established long since that solar radiation varies frequently by as much as half of one percent, and occasionally several times that. These variations occur in a series of cycles repeated every 9¾, 11, 21, 25, 39½, 46 and 68 months. But the fact that the outer atmosphere of the earth is receiving more heat from the sun on a certain day than on the day before does not mean that the whole surface of the earth will be that much warmer. The radiation must pass through an ocean of atmosphere at least 100 miles thick before it strikes the earth. Some parts of the globe become warmer and some cooler due to such factors as changes in degrees of cloudiness, effects on wind direction and intensity, effects on the movements of air masses in the high atmosphere, etc. But somewhere there is an initial effect—"a direct hit," as it is described by Dr. Arctowski. In seeking the point of this direct hit, he finds the most probable location is the vaguely defined surface which marks the bottom of the stratosphere—the point where temperature decreases with altitude comes to an end. Recently Dr. Arctowski announced his discovery of two stratospheres over the temperature zones of the world—a real one sloping toward the poles from the equator and the pseudostratosphere sloping upward from the poles toward the equator. His investigations indicate, Dr. Arctowski reports, that the solar radiation variations cause changes in the altitude of this surface over the tropics, where it normally is about 11 miles high, and that these changes proceed northward and southward in wave-like motions. An up and down movement of the tropopause causes a variation in the height of the highest clouds and in the movements of air masses, now considered perhaps the most fundamental factor in weather. These effects cause different precipitation effects in different parts of the earth.

R. H. O.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

REQUIREMENTS FOR 16-MILLIMETER MOTION PICTURE PROJECTORS.

The prospective user of 16-millimeter motion picture projectors is confronted with the problem of selecting from the various available makes and models, those which satisfy his requirements most economically. If specifications are to be prepared, the problem is that of describing the characteristics necessary to satisfy the requirements. Aside from price, the important factors involved are: Light output, definition of the image, steadiness of the image, freedom from flicker, durability, wear on film, and simplicity of operation.

The factors that determine the performance of a projector-light output, definition of the image, and random motion of the image can be measured by means of suitable objective tests. This makes it possible to specify satisfactory performance in terms of values thus obtained. The life of film when projected can also be measured by objective tests that give results suitable for comparison. The durability of a sample projector can be tested in a laboratory and the results certified, thus giving a good indication of the probable life. Other characteristics are of a nature so subjective that their specification is best made in terms of constructional details.

Circular C437, by Robert E. Stephens which has just been released, discusses in detail the requirements for a satisfactory projector, and describes procedures for making tests of the various characteristics that are involved. Values for these characteristics, representative of the better projectors, are given. This information will assist in the preparation of specifications for projectors and in the selection of ones that will meet the requirements. Copies of C437 are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents each.

* Communicated by the Director.

PRECISION OF MOTOR FUEL TESTING.

In 1934, the Coöperative Fuel Research Committee decided that sufficient data from coöperative tests were available to warrant an analysis with the object of determining the precision of knock rating and the factors affecting it. The Bureau, in carrying out this assignment, exhaustively analyzed 2,180 tests on 99 fuel samples. A report on this work was published in the *SAE Journal* for October 1936. By request, a second analysis was made of 6,386 coöperative tests run in 1936, 1937, and 1938, and the report was published in the same journal for October 1939.

In addition to determining the precision of knock rating, these two analyses established rather definitely the factors which influence it. Appropriate steps were taken to eliminate or minimize the adverse effects. The latest analysis, just completed by Donald B. Brooks and R. B. Cleaton, and based on 6,925 coöperative tests, shows the result of these changes.

The three analyses, covering 15,491 knock ratings, show that the precision of rating by both the ASTM Motor and the GFR Research Methods, has steadily improved. At present, about three tests out of four are in error by less than one-half-octane unit. Moreover, it appears probable that greater uniformity of technique and more attention to details can reduce the present average error to half its size, as the tests of some laboratories are now at this level.

Analysis of over 2,000 fuel inspection tests shows that gravity and vapor pressure measurements are made with comparable precision by all laboratories, but the distillation data indicate that some laboratories should conform more closely to the details of the test method if they are to improve the accuracy of their results.

OXIDATION OF CELLULOSE.

The potential scarcity of textile materials during the present emergency makes it more important than ever that adequate means be taken to prolong their usefulness. The useful life of a textile material does not begin until the fibers

of which it is made have undergone a series of mechanical and chemical treatments, some of which tend to reduce the strength of the material. Obviously, it is desirable to keep this loss at a minimum. For example, the undesirable yellowish color of cotton goods can be removed by treatment with mild oxidizing agents, such as dilute solutions of sodium hypochlorite or hydrogen peroxide, but although care is taken to avoid damage to the goods during this operation, some loss in strength may occur. Adequate control to prevent this type of damage requires a thorough knowledge of the conditions which produce it. Accordingly, the Textile Foundation's Research Associates have begun an investigation of the way cellulose is attacked by oxidizing agents.

The first reaction studied was that of cotton cellulose with per-iodic acid. Per-iodic acid is not used in bleacheries for processing cotton, but its known selective action made it desirable as a first subject of study in order to form a background for the proper understanding of the action of the common bleaching agents. It was found that in some cases, the action of this oxidizing agent does not result in a direct loss in strength but, rather, in a latent type of damage. Such damage is not indicated by usual strength tests until the bleached product is laundered or otherwise subjected to alkaline solutions. It appears that, in these cases, the reduction in the chemical stability of the cellulose molecules of the cotton is insufficient to impair appreciably the original strength of the material. Further treatment of the chemically unstable groups with alkalies results in far-reaching alterations in the molecular structure, thereby producing the loss in strength.

Research Paper RP1491 by Henry A. Rutherford, Francis W. Minor, Albert R. Martin, and Milton Harris, in the August *Journal of Research* gives the complete report on this reaction.

SUBSTITUTE FOR TINFOIL IN CURING DENTAL RESINS.

In coöperation with the Research Commission of the American Dental Association, a substitute for tinfoil has been developed that is quite satisfactory for use in curing dental resins.

A film of a soluble alginate is applied to the plaster. After the film has dried it is rendered insoluble and thus protects the resin during curing or molding.

Two solutions are required. The first is prepared by dissolving 5 or 6 grams of a soluble alginate (Kalco Products Co., San Diego, Calif.) such as potassium, sodium, magnesium, or ammonium alginate in 80 ml. of water. This may require several hours of constant stirring. When solution is complete add 20 ml. of glycerine. The first solution can be applied by dipping, spraying, or painting. After the film has dried, a second solution is applied.

The second solution contains metallic ions which will convert the soluble film to an insoluble film. A saturated solution of calcium chloride is satisfactory.

The halves of the flask, after the wax has been boiled out, are dipped in the first solution and allowed to drain and dry for a few minutes. A second dipping may be necessary if the solution is too thin or if the plaster does not retain a sufficient amount of the solution to form a continuous film. The halves are next dipped in the chloride solution for 5 or 10 minutes and then dried. The film can be removed from the teeth with a sharp needle-hook instrument similar to an explorer.

The flask is now ready for trial packing and with a moderate amount of care will retain the film until the cure is completed in boiling water.

The substitute has advantages over the foil in that it is easier to apply, takes less time at the bench, gives a smoother surface, and yields easier separations of the halves of the flask.

A patent application has been filed with proper assignments to the Secretary of Commerce to protect the Government and the dental profession. The invention was perfected by Dr. Irl C. Schoonover and George R. Dixon of the dental research staff stationed at the Bureau.

FORMATION OF AUSTENITE IN AN IRON-CARBON ALLOY.

The ease or difficulty with which a steel may be hardened, that is, its hardenability, is influenced by the size of its grains

at the time of quenching. To attain full hardening, coarse-grained steels usually may be cooled at considerably slower rates from the quenching temperature than fine-grained steels of similar composition. It is important therefore to understand the mechanism of the formation of these grains and to know the effects of different factors that influence their size at heat treating temperatures.

A study of the formation of austenite grains (that is, the grains in steels or alloys at relatively high temperatures such as those used in hardening) in a high-purity alloy of iron and carbon (0.50 per cent. carbon) has recently been completed by Thomas G. Digges and Samuel J. Rosenberg, and is reported in the August *Journal of Research* (RP1489). These grains are formed by a process of nucleation and growth. It was observed that in the initial stages of their formation these grains were always fine but that they often grew rapidly at temperatures lower than those ordinarily used in hardening. The dominant factor in establishing the grain size of this alloy was, therefore, the rate of growth, not the rate of nucleation.

FREEZING AND THAWING TESTS OF BRICK.

In Building Materials and Structures Report BM860, the results of 50 cycles of freezing and thawing were reported for 3,328 building bricks which had been subjected to the current standard method of freezing and thawing of the American Society for Testing Materials. Analyses of these data indicated that relatively few of the soft-mud bricks from the New England district failed in 50 cycles even though some of these bricks had physical properties indicating low durability, such as high absorptions, high saturation coefficients and relatively low strengths, and were classified by the manufacturers as either "light hard," "interior," or "soft." The failures that did occur during 50 cycles were, in nearly all instances, on bricks the properties of which were outside of the physical limits prescribed for the SW grade of ASTM Specification C62–41T. Other samples of these high absorption, soft-mud bricks performed poorly in exposure tests. To study these discrepancies between the results of 50 cycles of freezing and thawing and (*a*) the manufacturer's classifica-

tions, (*b*) the physical properties usually effective in separating durable from non-durable bricks, and (*c*) the results of exposure tests, 5 bricks from each of 10 New England brick plants were recently tested by J. W. McBurney of the Bureau's Masonry Construction Section. Each group of 5 bricks represented the extreme vertical range of the kiln. The results of this work were announced at the annual meeting of the ASTM on June 26.

The usual specification tests (absorption, saturation coefficient, and strength determinations) were made on all specimens. In addition, porosity was determined by the gas expansion method, and air permeability was measured using the method described by Stull and Johnson. The half bricks were then subjected to 50 cycles of freezing and thawing by method B of the ASTM standard, and the results recorded. An additional 125 cycles by a more severe method were then applied. The following conclusions are based on an analysis of the results of 50 and 175 cycles of freezing and thawing.

1. Fifty cycles by method B caused 15 failures out of 50 bricks, whereas 125 additional cycles caused 23 additional failures.

2. The following properties are sufficiently well correlated with the results of 175 cycles to permit limits to be established between the range for no failure, random failure, and complete failure: Porosity measured by the gas expansion method; water absorptions by 1-minute cold immersion, by 24-hour cold immersion, and by 5-hour boiling; saturation coefficients measured by porosity (W/V), and by boiling (C/B); and compressive strength.

3. The following pairs of values for the above listed properties represent the limits for the range of each property within which random failures and passes occur. The figures in parentheses represent the number of specimens within these limits. Porosity (2) 29.8–30.9 per cent.; water absorption by 1-minute cold immersion (9) 1.9–4.2 per cent.; by 24-hour cold immersion (2) 9.7–10.9 per cent.; by 5-hour boiling (5) 12.2–13.8 per cent.; saturation coefficient by porosity (W/V) (8) 0.61–0.65; by 5-hour boiling (C/B) (22) 0.73–0.80; and compressive strength (7) 5500–6400 pounds per square inch.

4. The following properties of the bricks are so poorly correlated with durability that limits cannot be established: Air permeability, number of capillaries per unit area, average radius of capillaries, and modulus of rupture. It should be emphasized that the above conclusions do not necessarily apply to types of bricks other than those tested.

Insofar as passing a freezing and thawing test is accepted as permitting a waiver of the physical properties required for acceptance in the SW grade of the current ASTM specification for building bricks, a more severe test than 50 cycles should be prescribed.

High Frequency Heat Used to Make Plywood.—(*Electrical World*, Vol. 117, No. 26.) High frequency current at approximately 2,000,000 cycles per second is now being applied to the manufacture of plywood. The application is found in two new presses recently installed in the plant of the Albany Plylock Division of the M. & M. Woodworking Company, Albany, Ore. The principle employed is that of a condenser charged with high frequency energy, producing heat in the dielectric which is the plywood itself. This heat sets the glue in a comparatively short time, thus speeding up plywood manufacture in the plant, with resulting economy. In the new high frequency presses the panels, with the wet glue between the piles, are stacked upon the bed of the press to a depth of 9 in. Then a metal plated caul board is inserted, above which is another 9 in. stack. This caul board is the positive plate of a condenser, while the metallic top and bottom members of the press constitute the negative plates. To these positive and negative plates, high frequency current is applied, the wet plywood acting as the dielectric. With this condenser the desired effect is the reverse of electric charge accumulation. Flow of the current through the dielectric distorts the molecules repeatedly and at these high frequencies produces molecular friction, releasing heat throughout the entire mass of the dielectric. This heat, evenly distributed, brings about the setting of the glue in a few minutes. The power at the points of actual application is 400 Kw. The original 4,400 volt alternating current is stepped up by transformers to 15,000 volts and converted to direct current by means of mercury arc rectifiers. This is thus converted to radio frequency current at approximately 2,000,000 cycles by means of mercury vapor amplifier tubes of large capacity. The tubes and transformer equipment are located in an inclosure on a balcony. A uniform flow of power as applied to the electrodes is maintained by a series of electrical controls responsive to the electrical capacity of the plywood bundle. The temperatures required in the plywood bundle are ordinarily between 160° and 180° F., although sometimes reaching 300° depending on the type of glue used.

R. H. O.

THE FRANKLIN INSTITUTE

LIBRARY NOTES.

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NOTES FROM THE BARTOL RESEARCH FOUNDATION

A COMPLETE PROPORTIONAL COUNTER ARRANGEMENT FOR COSMIC-RAY MEASUREMENTS *

BY

PAUL WEISZ AND W. E. RAMSEY.

An apparatus which has served successfully to study the ionizing capacity of individual particles of the cosmic radiation is described. The analyzing chamber is a carefully designed proportional counter tube filled with purified argon. Although this counter is working continuously, the amplifier has zero sensitivity unless a ray passes through a pre-determined path in the counter. This control is accomplished by a system of Geiger-Müller counters operating as a conventional telescope which "turns on" the amplification and recording mechanism for a period of time beginning with the passage of the ray and ending approximately 4×10^{-4} sec. later. During this time the amount of charge released in the proportional counter by this ray, and only this ray, is recorded. Certain general principles of proportional counter mechanism are discussed.

* An abstract of an article published in full in *The Review of Scientific Instruments*, 13, 258 (1942).

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Experiments with a Homologue of Dimethylazobenzene (Butter Yellow).—RICHARD W. LINTON AND LOUIS DESPAIN SMITH. Our purposes were first to synthesize a homologue of dimethylazobenzene capable of uniting with protein to form an antigenic complex, and second to use this complex in serological and immunological tests. The acid chloride of *p*-dimethylamino-*p'*-carboxyazobenzene was chosen, since it appeared possible that union with protein could be effected through the active chlorine.

p-Dimethylamino-*p'*-carboxyazobenzene was prepared by the diazo reaction from dimethylaniline and *p*-aminobenzoic acid. Twenty-five grams of this dye were refluxed with 75 ml. of thionyl chloride for one hour, and after cooling the mixture, the excess thionyl chloride was distilled off and the warmed flask evacuated for several hours to remove the last traces of the chloride. The dry material was dissolved by shaking with acetone and formed a dark red solution. After removing insoluble material by centrifugation, the acetone solution was poured into 15 to 20 volumes of cold water, with the resulting appearance of an orange-red cloudiness. After several days standing in the icebox a yellow-orange mass precipitated which was dried *in vacuo* to form an easily powdered cake. Yield, 11.0 g.; chlorine calculated for $C_{15}H_{14}N_3OCl$: 12.3 per cent. Found: 12.08 per cent., 12.68 per cent.

This compound was united to protein by partly dissolving and partly suspending 300 mg. of it in 35 ml. of ice-cold dioxane and pouring in 30 ml. of ice-cold horse serum, during mechanical stirring. The mixture immediately turned a bright yellow. The protein was then shaken in ice for 1.5 hours and precipitated and washed according to the method of Landsteiner and Chase (*Journal of Experimental Medicine*, **66**: 337, 1937). The final product was bright yellow in color and was readily soluble in normal saline to form a stable solution at a pH just alkaline to litmus.

A similar complex was formed by shaking the acid chloride with bovine serum. Of interest was the finding that the acid chloride would also unite with a suspension of *Escherichia coli* in alkaline solution. Such a complex is useful because of its great antigenicity with consequent ease of antibody production against the haptene.

It may be noted that several unsuccessful attempts were made to obtain the azide of the acid chloride by the method of Harington (*Biochemical Journal*, **34**: 838, 1940).

Each of four rabbits was given approximately 150 mg. of the horse-serum complex intravenously in 10 graded doses. The antisera obtained from these animals were precipitated by the bovine-serum complex. The zone of precipitation was quite short, precipitates appearing at dilutions of 1 : 200 and 1 : 2000 of the bovine-serum complex, and being absent at dilutions of 1 : 20 and 1 : 20,000. This haptene-antibody reaction was not inhibited by the saturation of the antiserum with butter yellow or with the acid chloride of *p*-dimethylamino-*p'*-carboxyazobenzene, although the relative insolubility of these two compounds in serum lessens the significance of this negative result. However, the adsorption of the rabbit antiserum with the acid chloride-*Escherichia coli* complex resulted in the removal of the antibody combining with the bovine-serum antigen. The results of ring and precipitin tests with such adsorbed sera were negative, indicating that the homologue of butter yellow was active as a haptene in the complex. Furthermore, the acid chloride-*Escherichia coli* complex was agglutinated, although with some difficulty, by antisera against the acid chloride-horse serum complex.

White mice were given three intraperitoneal injections of the acid chloride-horse serum complex at weekly intervals. The solution had 0.87 mg. of nitrogen per ml. Two weeks after the last injection, two of the mice were bled, and their sera pooled and tested against the bovine-serum complex. A definite reaction was obtained, a good ring being formed at a 1 : 100 dilution of the bovine-serum antigen.

Summary: A homologue of butter yellow containing an active chlorine atom has been synthesized, and linked to various proteins to form an antigenic complex. The injection of rabbits and mice with the acid chloride-horse serum complex

led to the formation of antibodies against this homologue of butter yellow.

Studies on Plasma Phosphatase Activity and on Blood Phospholipids in Rats with Obstructive Jaundice.—LEOPOLD WEIL AND MARY A. RUSSELL (*Journal of Biological Chemistry*, **144**: 307, 1942). In our previous work (*Journal of Biological Chemistry*, **136**: 9, 1940) it had been observed that the plasma phosphatase activity of rats was closely associated with the ingestion of certain unsaturated fatty acids. In these investigations the resorption of fats was inhibited by the ligation of the bile duct thus preventing the bile from entering the intestinal tract. As a result, the plasma phosphatase decreases sharply. The correction of this defect in fat resorption by the addition of ox bile to the diet practically eliminates the decrease in enzyme activity of the plasma. That the phosphatase activity does not come directly from the bile, but from other sources is shown by the fact that ox bile itself has no enzyme activity. In this case its only role is to correct the fat resorption, and it is this fat resorption that is responsible for the plasma phosphatase activity. That the sharp drop in the plasma phosphatase activity in jaundiced rats is not due to the inhibiting action of bile substances in the blood is shown by the fact that jaundiced rats fed on a diet containing ox bile developed all the symptoms of severe jaundice without lowering of the plasma phosphatase activity. The marked increase in plasma phosphatase activity observed in most cases of obstructive jaundice in human patients and in dogs supports this assumption.

For the determination of blood phospholipids an ultra micromethod has been developed, which permitted the estimation of phospholipids in 4 cmm. of blood. For the extraction of phospholipids with alcohol-ether from a few drops of blood in a micro test-tube, a shaking device was constructed, mounted at an angle of 45° and attached to a phonograph motor turned to a horizontal position (50 r.p.m.). During rotation, the alternating movements of the air bubble above the solvent and a stirring bead effected a thorough mixing. After one-hour extraction period the micro test-tubes were removed and centrifuged. The supernatent solvent was

transferred to a clean test-tube and placed in holes bored in a copper block, and the latter was placed on an electric hot-plate, the temperature of which could be regulated. With this procedure it was possible to evaporate the solvent without loss and to collect the lipids at the bottom of the test-tubes. The dry lipid residue then was oxidized with perchloric acid and the inorganic phosphate was determined colorimetrically.

A remarkably sharp increase was found in the blood phospholipids in rats with ligated bile ducts. This rise was observed both in the blood cells and plasma and was not corrected by the addition of ox bile to the diet. The difference in response of plasma phosphatase and blood phospholipids of jaundiced rats to a diet containing ox bile, however, requires further investigation.

Since fat resorption in the intestinal tract is impaired by the ligation of the bile duct, the great increase of blood phospholipids must be of internal origin. While no changes were observed in the total lipid and phospholipid content of the liver of normal and jaundiced rats, the total lipid content of the carcass of the jaundiced rats was markedly lower than that of the normal animals. It would appear that in the case of jaundiced rats in which normal fat resorption is prevented the body mobilizes the depot fat and converts it into phospholipids. The marked accumulation of these compounds in the blood (which serves as a transport agent) may be due to that mobilization and partly to the faulty fat metabolism of the diseased animal. The phospholipid content of the carcass was practically the same in both cases and may represent the essential components of the tissue cells.

BOOK REVIEWS.

ELECTRIC CIRCUITS AND MACHINERY, by Frederick W. Hehre and George T. Harness. Volume II, Alternating Currents. 635 pages, illustrations, 16 × 24 cms. New York, John Wiley & Sons, Inc., 1942. Price $6.00.

It has been the aim, for many years, in courses in alternating currents, to reduce the particular parts of the subject, which are susceptible to misunderstandings, misconceptions, and unsatisfactory explanations. There were several parts which could have been placed in this category. In fact, a close observer of students, and even of recent graduates, could in many cases predict difficulties when engaged in certain kinds of work. It is interesting to note in the preface of this book that at least some of these have been recognized and an attempt has been made at their elimination.

The treatment here is intended to be introductory to the subject generally. It is quite detailed and probably too long for some courses. The arrangement and sequence, however, allow for omission of certain parts throughout the text, without interruption in continuity. When advantage is taken of the omissions, they are available for use in answering queries. The general construction of the book is similar to other texts in use for many years. At the outset, after discussion of fundamental principles of alternating currents, the use of vectors is described. Immediately, then, single phase circuits are taken up, followed by polyphase circuits. The latter has been one of the stumbling blocks referred to above, and, to combat the difficulty, stress is laid on vector rotation in the explanation. The presentation is exceptionally clear.

Alternating current machinery is studied beginning with the transformer and proceeding with the alternator, the induction motor, the synchronous motor, and the single phase motor. Conversion devices is divided into two parts—those which are mechanical, such as the synchronous converter and electronic. It is gratifying to note that there is attention given to electronic devices—amplifiers, oscillators, and a study of vacuum tube circuits—as they are and may, in the future, be used considerably in connection with power applications. There is a chapter on alternating current instruments and, finally, on electric power transmission and distribution.

Extreme effort is made to present the subject clearly. This is a feature of the book. While there is very little not bearing directly on the subject matter under discussion, the manner of attacking each topic is impressive. There are a great many problems for exercise at the end of each chapter. A fair understanding of the work can be obtained without working out each one, of course, but the authors have recognized, apparently, the value of practice, even though it is at the expense of "sugar coating" the treatment. The book can be used to advantage as a text for electrical engineering students. With a minimum of help, also, it may be used for home study. As a reference work for practicing engineers, and as a means of refreshing knowledge of the subject, it is a safe, reliable, and authoritative book.

R. H. OPPERMANN.

BODY AND SELF, ONE AND INSEPARABLE, by Percy A. Campbell. 156 pages, 16 × 24 cms. San Francisco, Lawton R. Kennedy, 1942. Price $2.50.

In the first and larger part of this book, the author examines what he believes to be the relationship between body and self. In this, he defines body to be the material, physical, physiological organism of man. By self, he means body plus psychic powers. On this, he develops the thought that there is a chasm between the conscious self and the functioning body which is unexplainable, and generally man ignores this chasm. Proceeding onward, he examines the sensorium, which is the real conscious self, so that for practical purposes body and self are organically and functionally one and the self-same thing. Various phases of consciousness, covered in the same vein, are perceptions, the feeling of pain, and the use of the other senses—thinking, conceiving, the relation of knowing. There is much here that arouses the emotions either for or against the reasoning expressed. The matter is easy to read, the conclusions clearly drawn, but, aside from a pure thought-inspiring purpose, it is difficult to find any direct, definite, practical purpose served by the exposition.

The latter part of the book is devoted to reprints of occasional brief pieces of literature which were privately published, and quite widely distributed. They include the subjects of cosmic rays, matter, and its definition.

R. H. OPPERMANN.

VOLUMETRIC ANALYSIS, by M. Kolthoff and V. A. Stenger. Volume I—second revised edition, 309 pages, illustrations, 16 × 24 cms. New York, Interscience Publishers, Inc., 1942. Price $4.50.

As the title indicates, this book presents the theoretical principles of volumetric analysis as a means of furnishing a basis for determining the general applicability of a method, as well as a means of seeking out all factors that may affect results. The book was originally published in German in 1927. It was translated into English by Prof. N. H. Furman of Princeton University, and published in 1928. The present work is a thorough revision and enlargement of its predecessors.

There are, in all, ten chapters beginning with fundamentals of volumetric analysis, and proceeding through the principles of neutralization and ion combination reactions, titration curves, the principles of oxidation-reduction reactions, which are the bases for a great number of volumetric methods, the action of indicators, titration error, reaction velocity, adsorption and co-precipitation phenomena, volumetric methods of organic analysis, and methods for the determination of the equivalence-point.

At the end of the book, there appears an appendix containing tabular information useful in analytical work, an author index, and a subject index. The principles of the subject are clearly presented, and in sufficient detail to form the basis of the second volume, dealing with the practical performance of titration methods.

R. H. OPPERMANN.

VITAMINS, by H. R. Rosenberg. 674 pages, illustrations, 16 × 24 cms. New York, Interscience Publishers, Inc., 1942. Price $12.00.

It is only in recent years that the chemistry and physiology of vitamins has been known. The subject has been one in which there was a great deal of research,

and although development has been rapid there is still much unknown. There is tremendous literature on research activities scattered over a wide range. The situation is ripe for a summation of what has taken place, and this will contribute toward furtherance of knowledge and inspire development. This book is a monograph which gives guidance through our present-day knowledge of the field.

It begins with a definition of the vitamins, distinguishing this group sharply from the hormones, and from other essential and non-essential food constituents. A new classification for compounds, which have the dual character of vitamins and structural building units or suppliers of energy, is introduced. Then, each vitamin is discussed separately, emphasis being laid upon the chemistry and the physiological action of these compounds. The chapters on each vitamin start with a review of the nomenclature and a tabulation of the historical development, followed by a paragraph on the occurrence of the vitamin. The main discussions on the chemistry and physiology follow. Under the chemistry of each vitamin, the procedures used for the isolation of the vitamin, the proof of the chemical constitution, and the synthesis of the vitamin are reviewed separately. There are special paragraphs on industrial methods of preparing the vitamins and on their biogenesis. The specificity of the vitamin action is treated separately. The determination of the vitamins is subdivided into physical, chemical, biochemical, and biological methods and is followed by a paragraph on the vitamin standards. The physiology of plants and microörganisms is separated from the animal physiology, which is subdivided into the metabolism of the vitamin, the physiological action, and the mechanism of the vitamin action. The relation of each vitamin to other vitamins, to hormones, and to inorganics is presented in special paragraphs. This is followed by a short review of the present-day knowledge of the pathological aspects, the hypovitaminoses, avitaminoses, hypervitaminoses, and paravitaminoses, with a special section on clinical test methods. Finally, the vitamin requirements are briefly stated. The book ends with a list and abstracts of vitamin patents, which have been issued in the United States, Great Britain, Germany, and France, arranged in a manner similar to that of the main text.

The work is an exhaustive compilation, abstract, and classification of a great many literature references which are expertly woven into an account of the present state of knowledge. It is invaluable as a research tool and reference.

R. H. OPPERMANN.

FOUNDATIONS OF ASTRONOMY, by W. M. Smart. 268 pages, illustrations, 15 × 23 cms. London, New York, Toronto; Longmans, Green and Co., 1942. Price $4.20.

It is important, today, for a greater number of persons to become familiar with astronomy to the extent necessary to solve problems in navigation. The author of this book was formerly Instructor Lieutenant in the Royal Navy, and was joint author of the Admiralty Manual of Navigation. He offers this book with the hope that it will be of value as an introduction to the Service manuals. It, therefore, can be looked upon as providing a background for practical matters, although there is much foundation laid for the more advanced studies in astronomy.

Opening with a general discussion on the geometry of the sphere, it proceeds to consider some principles of fundamental character in relation to the specification of the positions of heavenly bodies on the celestial sphere. On this is built the treatments of right ascension and mean time. The solar system and the law of gravitation, followed by atmospherical refraction, are later topics. An exceptionally clear presentation is that on the parallax, which includes the value of the solar parallax, recently announced by the Astronomer Royal (Dr. H. Spencer Jones). There is a brief, but clear, description of the main features of the sextant and directions for determination of position on the earth. Special consideration is given to the moon, its phases, its surface characteristics, and its movements. Likewise, the stars are covered, their magnitudes, colors, and spectrum. The final chapter is devoted to a description of the main features of several astronomical instruments, including the telescope, the theodolite, and the filar micrometer. Appendices contain astronomical constants, elements of planetary orbits, dimensions of the sun, moon and planets, the Greek alphabet, and elements of the satellites. There are questions at the end of each chapter, and the answers to them are given in the back of the book adding much value to the book for home study. It can be recommended for this and equally well for classroom work. It is brief and to the point.

R. H. OPPERMANN.

CHEMICAL REFINING OF PETROLEUM, by Vladimir A. Kalichevsky and Bert Allen Stagner, Ph.D. Revised edition, 550 pages, illustrations, 16 × 24 cms., New York, Reinhold Publishing Corporation, 1942. Price $7.50.

There is probably no technical subject of greater importance than the refining of petroleum. This has been so for many years, and, as time passes and knowledge and technique are improved, the field of possibilities seems to become larger. The resulting demand for petroleum products is ever increasing, not only for the same and better products but for new ones. As a consequence, a myriad of chemical refining and treating processes have been developed, descriptions of which appear in a diversity of literature from practically all countries of the world. To realize the difficulty of keeping familiar with the progress made will facilitate recognition of the value of a monograph which provides a review of these processes in one volume. The book at hand attempts to do this, compactly and completely.

An American Chemical Society Monograph, this book was first published seven years ago. It is now revised and much has been entirely rewritten. The material it contains has been collected from the literature and, also, contributed by the authors from their own experience. There are some eleven chapters in the book. It starts out with a general discussion on the composition of petroleum, its classification and principal commercial products, and then, treatment with sulfuric acid is taken up. One point made here is that strong sulfuric acid acts on many constituents of petroleum oils forming solution and reaction products known as acid sludge. This topic is selected as the next in line for coverage, and accordingly, sulfuric acid sludge and hydrogen sulfide, with the recovery and manufacture of sulfuric acid, is the heading of chapter three.

Proceeding further, treatment with alkaline reagents is discussed both in their use following acid treatment and before. Considerable space is devoted to

the subject of sweetening, involving elemental sulfur and mercaptans, and the general subject of the reduction in the total sulfur content in light petroleum products. The next subject is the application of applying adsorbents to oils. The methods of percolating the oils in the liquid state, through a column of granular adsorbent materials, mixing the oils in the liquid state with finely divided adsorbents, and then separating them by filtering, and passing the oil vapors through a column of granular adsorbent materials are all described. Likewise, refining with solvents, the processes themselves, and their relative position in petroleum refining is presented.

What might be considered another section of the book consists of the last four chapters. Here there are treated the subjects of detonation and antidetonants, inhibitors of atmospheric oxidation of petroleum products, gums and cracked petroleum products, and deterioriation of lubricating and similar oils. Appendices contain a supplementary list of U. S. Patents on petroleum refining and various tabular data of value. There are a patent index, author index, and subject index.

The book is suitable, in every respect, as an addition to the A. C. S. Monograph Series. It reflects a thorough knowledge of the literature and the situation of the art. It is an invaluable tool for those interested in the subject.

R. H. OPPERMANN.

ESSENTIALS OF ASTRONOMY, by John Charles Duncan. 181 pages, illustrations, 15 × 23 cms. New York and London, Harper & Brothers, 1942. Price $1.85.

Here is a little book that contains a fund of interesting and useful information. The author, in the preface, states that the two principal aims of the book are to provide a satisfactory course that is shorter than the usual college year, and to develop the subject in the order in which the student's interest is awakened. The book is testimony to the great extent that these aims have been achieved.

The method of treatment, necessarily, must be non-technical, yet the completeness and accuracy of the facts covered is surprising. Starting out with a discussion on the appearance of the sky, there is pointed out the changes which take place with the passage of time, and these changes are explained. Astronomical instruments are described, including a part on the nature of light and its utilization in the instruments. After this, the structure and behavior of the universe, as revealed by the use of instruments, is given attention. Appendices contain much useful tabular data, and there are numerous star maps and other illustrations which add much to the value of the book.

The presentation is easy to read and has much appeal. Enough information is presented to enable the average person to obtain a great deal of appreciation of the wonders of the heavens above.

R. H. OPPERMANN.

ADVANCES IN COLLOID SCIENCE, by Elmer O. Kraemer, Ph.D. Volume one, 434 pages, illustrations, 16 × 23 cms. New York, Interscience Publishers, Inc., 1942. Price $5.50.

This is volume one of what is intended to be a series of volumes to provide a medium in which recent significant discoveries or advances in Colloid Science, either experimental or theoretical, may be presented in a more comprehensive

and unified fashion than is possible in regular periodicals. The work is edited by Elmer O. Kraemer, Ph.D., of the Biochemical Research Foundation of The Franklin Institute in collaboration with Floyd E. Bartell, Ph.D., of the University of Michigan and S. S. Kistler, Ph.D., of the Norton Company.

There are sixteen contributors to this volume one. Among the contributions, there is included one by P. H. Emmett who describes a proposed method for measuring surface areas by low temperature adsorption isotherms. A review is made of the permeability method for determining specific surface of fibers and powders by R. R. Sullivan and K. L. Hertel, after which there is appended a list of 138 references in the literature. Later, Arne Tiselius presents a new method of adsorption analysis. A very interesting discussion, from a colloid-chemical point of view, is that on the creaming of rubber latex by G. E. Van Gils and G. M. Kraay. Likewise, is the discussion of the application of the electron microscope to the determination of sizes and shapes of colloidal particles by Thomas F. Anderson. Other subjects covered include recent developments in starch chemistry, the constitution of inorganic gels, streaming birefringence and its relation to particle size and shape, and synthetic resin ion exchangers.

The contributions are presented in good fashion. The method of collection and presentation, which is the purpose of this series of volumes, promises to be a real aid to those wishing to be informed and kept up to date on this very important subject.

R. H. OPPERMANN.

PUBLICATIONS RECEIVED.

The Methodology of Pierre Duhem, By Armand Lowinger. 184 pages, 16 × 23 cms. New York, Columbia University Press, 1941. Price $2.25.

Molecular Films, The Cyclotron and The New Biology, essays by Hugh Stott Taylor, Ernest O. Lawrence & Irving Langmuir. 95 pages, illustrations, 16 × 24 cms. New Brunswick, Rutgers University Press, 1942. Price $1.25.

Bell Telephone System, Monographs: B-1340, The Rate of Oxidation of Copper, by Addison H. White and Lester H. Germer. 14 pages, illustrations. B-1341, The Crystallinity of Cellulose Esters, by W. O. Baker, C. S. Fuller, and N. R. Pape. 21 pages, illustrations. B-1343, Electron Diffraction Studies of Thin Films—III, by L. H. Germer. 10 pages, illustrations. Three pamphlets, 15 × 23 cms. New York, Bell Laboratories, 1942.

Elementary Physical Chemistry, by Merle Randall and Leona Esther Young. 455 pages, illustrations, 6 × 9 cms. Berkeley, Randall and Sons, 1942. Price $4.50.

Isomerization of Pure Hydrocarbons, by Gustav Egloff, George Hulla, and V. I. Komarewsky. 499 pages, illustrations, 16 × 24 cms. New York, Reinhold Publishing Corporation, 1942. Price $9.00.

CURRENT TOPICS.

Glass-Metal Seal.—(*Chemical & Metallurgical Engineering*, Vol. 49, No. 5.) Tight seals between iron and glass, eliminating the need for nickel and cobalt for wires leading into certain types of vacuum tubes are now being made in accordance with a new process developed by Dr. Albert W. Hull and Dr. Louis Navias of the General Electric Research Laboratory. Since nickel and cobalt are used in many ways for war equipment, and their supply is extremely limited, the new invention is an important one for certain applications. It permits tight seals because the glass compositions are developed to expand with heat at the same rate as that of the metal. The series of different glass compositions can be used with iron and certain iron alloys. One consists of 45 per cent. of lead oxide and 5 per cent. of calcium fluoride. The rate of expansion of this glass is very close to that of iron. A related and separately patented invention of Dr. Navias is useful when a glass containing lead is sealed in contact with iron. Ordinarily in such instances the lead atom migrates from the glass into the metal, thus weakening the joint. Dr. Navias proposed placing a thin layer of lead-free glass directly over the metal, then sealing the lead-containing glass to that. The thin glass layer prevents the lead from reaching the iron, yet is not thick enough to crack and let the air in.

R. H. O.

America's Drug Plants.—E. C. HIGBEE of the staff of the Office of Foreign Agricultural Relations of the Department of Agriculture, stated in a recent issue of *Agriculture in the Americas* that the Americas were in the drug plant business long before the days of Christopher Columbus. Early Indian medicine men of the Western Hemisphere catalogued their medicinal plants as conscientiously as any modern scientist records his findings. Rites of mystery conducted in the Orinoco Valley of Venezuela and the Yungas region of Bolivia relied for effect upon the virtues of ipecac, coca and scores of other native plants with real or fancied curative powers. For a large number of drugs, the world still depends chiefly on the Western Hemisphere. Not all the drugs on which the Western Hemisphere depends, however, have been produced by its own farmers. While the hemisphere can grow almost any plant known in the world, it has not been considered practical to try to compete in drugs with cheap labor conditions in the tropical regions of Asia,

Africa and certain parts of Europe. American growers have specialized in wild products that brought good returns and have attempted little cultivation of drug plants. Perhaps the best known of the Hemisphere's deficit drugs is quinine, obtained from the bark of the cinchona tree. Today this American native, long neglected in its homeland, is being planted with skillful care in plantations in Central and South America in the hope that some day every malaria victim in the Americas may be supplied with home-produced quinine at the lowest possible cost. United States farmers and drug houses are preparing to make small but adequate plantings of deadly aconite, which is a helpful heart medicine and sedative when properly administered. In the past it has been imported from Europe. There will be increased production this year of the important sedatives and heart medicines, belladonna and digitalis, and the anodyne, henbane. The laxative seaweed, agar-agar, is being gathered off the coast of Southern California, since supplies from the China Sea have been cut off. Not only can the Americas grow unfamiliar drug plants, but there seems real possibility that the world's drug store can be augmented through further investigation of native American plants not now fully appreciated.

R. H. O.

Professional Institute Awards.—JOHN PATTERSON, B.A.Sc., M.A., F.R.S.C., of Toronto, Controller of Meteorological Service, Department of Transport, and M. F. GOUDGE, B. A., B.Sc., of Ottawa, Mineral Technologist of the Bureau of Mines, Department of Mines and Resources, were awarded the 1942 medals of the Professional Institute of Civil Service of Canada. Both recipients are Canadian-born scientists. The awards were made for the most outstanding administrative and scientific contributions by professional or technical workers in the Dominion or Provincial Civil Service. The medal for the outstanding administrative contribution was awarded to Mr. Patterson for his long and brilliant career in scientific work and administration which have earned for him universal recognition as the leading figure in Meteorological Science, and for his contribution to Canada's war effort by meeting the operational needs in weather forecasting of the R.C.A.F., the British Commonwealth Air Training Plan, the Trans-Atlantic Ferry Command, and also the Royal and Royal Canadian Navies. The medal for the most important scientific contribution was awarded to Mr. Goudge for his discovery of valuable deposits of brucite, a magnesium metal, and for developing a process for its concentration and making it possible to obtain pure calcined brucite or magnesia, at a low production cost, in a form highly suitable for use

in basic refractories and for making magnesium metal so much needed in the production of munitions and armament in Canada's war effort. This contribution to metallurgical science has also made possible the development of limestone deposits which previously had relatively small economic value, thus augmenting Canada's known mineral resources by many millions of dollars.

R. H. O.

Calorimetric Method for Determining Efficiencies of Electric Machines.—VICTOR SIEGFRIED, CHARLES W. THULIN and senior students in electrical engineering at Worcester Polytechnic Institute describe this method in *Electrical Engineering*, Vol. 61, No. 7. The classical form of the calorimetric method makes use of the basic principle that all losses are converted into heat. Measurements of thermal values from specific heat of the coolant, its volume, and temperature rise, have involved uncertainties and difficulties which have tended to discredit the method in the past. Now, however, improvements to the method allow for a direct indication of losses of electrical machinery. Test work was done on two machines, one an induction motor and the other a d-c motor of comparable size. The equipment consists of a double-walled calorimetric box of heat insulating material to enclose the machine under test, a constant-speed blower to force air through the box, thermocouples differentially connected between the inlet and outlet ports of the box, power-measuring instruments in the leads to the test box, and heaters inside the box near the test machine. The machine is operated under load, and power input and thermocouple measurements are made. The machine is then operated at no load and additional heat is supplied by the heaters so that the same thermal conditions result. The calibrating power is thus the sum of the no-load input to the machine and the power to the heaters. In the case of the induction machine, the power may be introduced into the machine by raising the applied voltage to the point of current limitations. This is a comparison or substitution method which determines with high accuracy the total losses. The method permits good comparative data to be taken even under poor calorimetric conditions. Losses measured by it compare directly and favorably with those of other methods of high accuracy and show a final stray load loss value very close to those from other tests. Further attention to the calorimetric method will doubtless bring forth other advances in its use.

R. H. O.

Feldspar for Extinguishing Magnesium Incendiary Bombs.—Because the problem of handling incendiaries may become of com-

mon concern, the Geological Survey sought a solution which would involve the least expenditure for equipment or material supplies, and yet be as nearly foolproof as possible in handling. In the use of feldspar, ground to pass a 10-mesh screen and be retained by a 200-mesh screen, Geologist W. W. RUBEY and Chemists MICHAEL FLEISCHER and J. J. FAHEY believe they have found an effective answer. The effectiveness of this material has been demonstrated on a small scale in the Geological Survey laboratories, and on one-pound bombs at Edgewood Arsenal of the Chemical Warfare Service. Among the advantages of feldspar are: (1) It is inexpensive; (2) It is readily available; (3) It is easily handled; (4) It is effective. With a lower melting point than sand, feldspar quickly forms a protective coating over molten magnesium which cuts off the supply of air from the magnesium and actually stops it from burning and its flame from spreading. It is superior to mixtures containing salt, pitch, ashes or fine powders as it does not burn, give off smoke, blow out, or scatter appreciably from the intense heat of the incendiary material. In laboratory experiments, it was shown that when magnesium or an incendiary bomb was ignited and placed on a pine floor or board and covered with ground feldspar, the fire was extinguished so quickly and the supply of oxygen was cut off so effectively that the wood was charred only to a depth of less than half an inch. Moreover, only about 50 per cent. of the magnesium was consumed in most tests with feldspar, the balance being put out before it burned. In most of the experiments, the rock used consisted largely of soda-lime feldspar. This rock, locally called aplite, is quarried in Amherst and Nelson Counties, Virginia, where there is an abundant supply. Potash feldspar (orthoclase or microline) is equally as effective, also fusing at about 2,100° F. The principal source of potash feldspar is in exceedingly coarse-grained granite, called pegmatite.

R. H. O.

Plastic Tubing A "War Baby."—C. B. BRANCH AND D. L. GIBB. (*Heating, Piping and Air Conditioning*, Vol. 14, No. 6.) It has been said that the machine age began with the invention of the wheel but certainly the wheel is little more essential to the whole structure than the tube. Man depends on some form of hollow conductor for the delivery of food and drink, for heat, light, transportation and sanitation. It is not strange then that a reduction in the amount of tubing available should present serious problems to innumerable persons and industries; nor that the new plastic tubings are of general interest. One such tubing is made of a thermoplastic formed by the copolymerization of vinylidene and

vinyl chlorides. The basic polymer is tasteless, odorless, nontoxic and nonflammable. The tubing is made in seamless continuous lengths and at present is available in sizes from ⅛ to ¾ in. diameter with varying wall thicknesses. Present trends point to the fabrication of even larger tubing in the near future. This basic plastic is particularly suited for tubing because of its relatively sharp melting point and resultant retention of physical properties within the service temperature range. Another advantage is its comparatively high bursting pressure. Some individual values on ¼ in. O.D. by 0.037 in. wall thickness at 77° F. have been as great as 2250 psi. When the temperature is decreased from 77 to 32° F. the working pressure is approximately doubled; at the same time this change in bursting pressure is accompanied by a corresponding reduction in impact strength. This tubing may be joined by some of the same types of connectors commonly employed with metal tubing. These include flared, compression, welded and flanged fittings. For the smaller sized tubings now available, flared types are very satisfactory. In bending the tubing at room temperature, the tendency to kink decreases with increasing wall thickness. Fabrication such as bending or forming to permanent desired shapes is easily accomplished. Bends can be made to an inside radius as small as one half the diameter of the tubing.

R. H. O.

Sprue Mill Recovers Sand.—(*The Iron Age*, Vol. 149, No. 26.) A system of cleaning excess sand off the sprues and gates of castings before the metal is remelted in cupolas, and a means of separating all miscellaneous iron from all waste sand is in operation at the foundry of Pontiac Motor Division of General Motors Corporation. The equipment consists of a sprue mill, a loading hoist, an apron conveyor, a belt conveyor, and a waste sand elevator. There is also a dust collector to remove large amounts of the dust created in the sprue mill. This equipment will handle a mixture of sand and iron or straight loads of gates and sprues at the rate of about 30 tons per hr. Iron particles larger than 1 in. in diameter are dumped on an apron conveyor which returns them to the iron yard underneath the charging crane. This iron is free and clean from all sand, due to the tumbling action of the sprue mill. The sand and small particles of iron pass through a screen at the end of the cylinder to a belt conveyor. This belt conveyor has a magnetic pulley which separates all magnetic material from the sand. The sand is delivered by bucket elevator to an overhead storage hopper, placed high enough so that a dump truck can be loaded from the discharge spout. Fine iron so recovered is carried by a small belt conveyor to the yard

underneath the charging crane. In connection with the tumbling mill there is a large fan and dust collector that removes the fine dust from waste materials. Such dust is collected by a wet collector. About 30 tons of sand a day are removed from the overhead hopper and returned to the foundry sand system. The remainder of it is hauled to the dump as waste. Since this system was put into operation, Pontiac has made a practice of putting all waste sand through a tumbler. As a result, it is saving about 15 to 18 tons of iron per day formerly lost through faulty magnetic separations and in the form of sweepings on the floor.

R. H. O.

Electrical Charges Produced by Flowing Gasolene.—S. S. MACKEOWN AND VICTOR WOUK. (*Industrial and Engineering Chemistry*, Vol. 34, No. 6.) The flowing of gasolene in pipes generates static electrical charges which are sometimes capable of producing a spark that may ignite a combustible mixture of gasolene vapor and air. Although suitable precautions have been taken in the oil industry to prevent the accummulation of these charges and eliminate the hazard due to an electric spark, very little is known regarding the magnitude of the charges. A vacuum tube meter was built which has proved satisfactory in measuring these extremely small currents. Approximately three hundred measurements were made of the currents produced when gasolene is loaded into a tank truck at a filling rack. A large range of filling rates from 800 to 5 gallons per minute with a pipe of the same diameter gave results which showed that in practically every case the amount of current produced is directly proportional to the rate of flow. Measurements on three different types of gasolene sold by four companies show that for some unexplained reason there is considerable difference in the charge developed by gasolenes refined by different companies. In all cases currents from 10^{-7} to 10^{-8} ampere were measured with the normal rate used in filling tank trucks. It was shown that it may be possible to generate a sufficiently high charge to produce an electric spark, if the truck is insulated from the ground. While there is no method of preventing the production of these charges, safety demands that means be used to prevent these charges from accumulating and raising the truck to a sufficient potential to produce a spark. When a truck is unloading gasolene at a service station the current produced is very small because of the low rate of flow used. The hose employed contains a metallic wire to make electrical connections between the truck and the underground tank. This wire offers such a low resistance that no appreciable voltage can exist on the truck. In the ordinary filling of a passenger car at

a service station not enough charge is generated to create any hazard even if the car is perfectly insulated.

R. H. O.

1,327,000 Hp. at Boulder Dam.—(*Power*, Vol. 86, No. 7.) Boulder Dam water and power project is approaching its final stage of completion. When the contract was let for its construction, March 1931, no one could foresee that in 10 years nearly 1,500,000 hp. of power generating capacity would be installed or on order for its power plant and that it would generate 3,224,423,000 kw. hr. in 1941. Boulder Dam has many unique features. It is 730 ft. high from the lowest point on its bed rock foundation to its crest, almost 200 ft. higher than any other dam in the world. It is 650 ft. thick at its base, measured up and down stream. With a crest length of 1180 ft. it contains 3,400,000 cu. ft. of concrete. This is a greater volume of material than in the great pyramid of Cheops in Egypt that held the record for 3000 years. This dam also forms the largest artificial reservoir in the world, now known as Lake Mead. When filled to the top of the spillway gates, it will store more than 31,000,000 acre-ft of water. When it is realized that most of the world's reservoirs have a capacity of 500,000 acre-ft. or less we get some idea of the size of Lake Mead. To build the dam the river was diverted around the site through four concrete lined tunnels 50 ft. in diameter. Since the tunnels were closed in February 1935, to fill the reservoir, the river has been under complete control. In June of that year nearly 4,000,000 acre-ft. of water was stored back of the dam. If this water had gone down the river uncontrolled it would have caused destructive floods. Later in the year, river flow dropped to 5000 sec. ft. above the dam, which would have resulted in a serious irrigation water shortage. Because of the water stored during the June flood a flow of 10,000 sec. ft. was maintained below the dam, the amount needed to meet irrigation requirements. It required the total flow of the river for seven years, less that needed for irrigation and power generation, to fill the reservoir.

R. H. O.

Substitute Textiles.—Substitute textiles—and substitutes for substitutes—for clothing and other purposes are expected to be much in evidence. The American Home Economics Association meeting in Boston recently heard reports of changes under way and in prospect from Ruth O'Brien and Margaret S. Furry, textile specialists of the Bureau of Home Economics, U. S. Department of Agriculture. Both speakers emphasized "functional" trends, treat-

ment of fibers and textiles to give them the special qualities desirable where they are to be used, clothing designed to fit the work conditions where it will be worn. Miss O'Brien, who is Chief of the Division of Textiles and Clothing in the Bureau, suggested that the consumer will return to "simpler, more sturdy clothes—perhaps to more sportswear types with hose and shoes and everything else in keeping." We will be concerned, she said, not with the sheerness of hose, but with their durability; not with the elegance of dress, but how well it functions. Miss Furry, textile chemist in the bureau, gave more detailed information as to prospects for new fibers and for modification and improvement of old fibers. Research in this field has been widespread in recent years and has produced such fibers as rayon, nylon, vinyon, and casein fibers. She mentioned a new round plastic yarn prepared from rubber hydrochloride, that is strong, elastic, and claimed to be impervious to water, oil, mold and moths. Textile fibers other than casein fiber are being developed from natural proteins. She said it is claimed that soybean fiber can be produced at half the cost of sheep's wool, and has a warm soft feel and a high degree of resiliency. It is desirable for automobile upholstery among other uses. Other sources of synthetic fibers on which research is now active are: peanuts, corn, fish protein, yucca, the bark of redwood trees, and glass. Recent textile research has looked to fundamental changes in textile fibers by altering the molecular structure of the fiber cells, or by applying chemical finishes that give them increased usefulness and durability.

R. H. O.

Wood Pipe Can Also Serve.—ROBERT TURNER of the National Lumber Manufacturers Association states that in a typical 35,000 man cantonment a water system of wood pipe would save 9,193,000 pounds of iron and $222,140. These figures come from a report by Beasley & Stoehr, hydraulic engineers of Portland, Oregon, who recently made a study of the relative merits of wood stave pipe versus cast iron, basing their analysis on 1941 prices of Class 150 bell and spigot cast iron pipe with caulking materials and untreated, machine banded wood pipe, banded for 250 ft. head with galvanized wire and fitted with creosoted collars. This study showed a dollar saving of 39½ to 58½ per cent., depending on size, while metal savings ranges from 86½ to 91½ per cent. The idea of using wood pipe in military establishments is by no means new. It was used by the A. E. F. during World War I with excellent results. One of its greatest assets was its lightness. Wood pipe can be used advantageously for drainage, water supply, or sewage. It costs less than one-half as much to install, and it can be laid by

common labor, whereas skilled or semi-skilled labor is required to lay cast iron pipe. Wood pipe is made in two general types: machine banded and continuous stave. Machine banded wood pipe is manufactured in random lengths up to 20 feet, 2 to 24 inches inside diameter, spirally wrapped with heavy, galvanized steel wire. Each joint, complete with coupling, is a finished piece of pipe ready for installation. After thorough seasoning, the lumber is milled to the pipe stave pattern, the inside and outside faces milled to the concentric circles of the pipe, and the edges to the true radial lines with a small groove on one edge and a corresponding tongue on the opposite edge. The staves are assembled and clamped into position, then spirally wrapped with heavy galvanized steel wire. Where chemical conditions demand, the pipe can be banded with other metal or alloys. The ends are turned to fit the desired coupling. Finally, the outside is usually heavily coated with hot coal tar or pitch to protect the wire, then rolled in fine sawdust. Any type of coating or fabric covering can be supplied. Each joint of pipe is fitted with its necessary couplings at the factory. All that is necessary on the job is to drive the joints together. Swelling of the wood makes the connection tight; no bolts, gaskets, or packing are needed. Continuous stave wood pipe is made from 6 inches to 20 feet inside diameter and is used principally in sizes longer than 24 inches. It is shipped knocked down, completely manufactured and ready to assemble. It is fitted with individual steel bands connected with malleable iron pipe shoes. The joints connecting the staves end to end are made either with galvanized steel tongues or malleable iron butt joints. Under normal conditions, wood pipe will give excellent service for 30 to 50 years without appreciable maintenance cost.

R. H. O.

Seek Home Grown Poisons.—Cutting off of normal sources of supply has further emphasized the need for continued research for new insecticides that come from native plant sources. R. C. ROARK, in charge of insecticide investigations in the U. S. Department of Agriculture, in discussing this possibility, also summarizes experience with the synthetic insect poisons. Many synthetics, he says, have been effective in laboratory tests, but only a few have proved their worth in pest control. Liquid hydrocyanic acid, methyl bromide, chloropicrin, ethylene oxide, ethylene dichloride, paradichlorobenzene, carbon tetrachloride, and carbon disulphide are widely used fumigants. Several thiocyanates are used as contact poisons. The only synthetics effective as stomach poisons are phenothiazine, xanthone, and a few others, most of which have

only been used experimentally. It has not been possible, says Roark, to synthesize the pyrethrins or rotenone or their related compounds. Although the synthesis of nicotine is chemically possible, it is cheaper to grow the plant which yields the poison than to manufacture nicotine as a chemical.

R. H. O.

Army Turns to Wood.—The Army has definitely decided to change from steel to wood bodies for all cargo trucks, and intends to have a production schedule of 1000 bodies or more per day. Five types of cargo truck bodies heretofore constructed of steel are affected. A series of meetings were held recently between representatives of the National Lumber Manufacturers Association, the War Production Board and engineers at the Quartermaster Depot, Holabird, Maryland, on lumber specifications and the estimated quantities of suitable lumber available. Information on the latter was gathered from regional lumber associations and also supplied directly by many individual producers. National Lumber Manufacturers Association representatives reported that, while a survey indicated that there would be sufficient lumber for the proposed program—approximately 350,000,000 feet of hardwoods per year—the existing supply was not of a sufficiently low moisture content to be used without kiln drying.

R. H. O.

Hollow Drill Speeds Micro-Sampling.—Much time is saved by by using a tubular drill for extracting solid test samples from castings, forgings, rolled and welded parts at the Westinghouse Electric and Manufacturing Company, East Pittsburgh works. In addition, it is usually possible to sample without weakening the part being tested, and also the surface material (one end of the cylindrical sample) is preserved for inspection. The method replaces the slow and laborious procedure so commonly used to saw out specimens for microscopic analysis. Essentially a tubular member having a number of cutting teeth at one end, the drill contains a removable centering device consisting of a pin and spring inside the hollow shaft. Held in the chuck of an ordinary stationary or portable air, electric, or hand drill, no jigs are required and the drill is operated in the conventional manner. To use, a pilot hole approximately $\frac{1}{8}$ inch diameter and $\frac{1}{8}$ inch deep is made with a standard twist drill. The tubular member is then clamped in the chuck, the spring and the centering pin placed in the tubular member. The centering pin is positioned to extend beyond the drill teeth and the nipple is inserted in the pilot hole. When the drill has cut into the piece

about $\frac{1}{16}$ inch, it is withdrawn to permit the pin and spring to drop out. Drilling is then resumed to the desired depth; the solid core formed inside the tubular shaft is removed from the part by flexing until it breaks off at the base.

R. H. O.

Chromium Research.—Aided by an appropriation from the Congress, the Bureau of Mines has embarked on more intensive studies of processes developed by its metallurgists to increase the Nation's output of chromium, it was recently revealed by Dr. R. R. SAYERS, Director of the Bureau of Mines. Two processes, which appear destined to speed the flow of chromium to plants in unprecedented volume from domestic sources, will be emphasized in further research and experiments by the Bureau, Dr. Sayers said. These are: (1) A benefication process for low-grade ores which has successfully passed all tests made so far and has proved to merit large-scale pilot tests to determine optimum operating conditions for commercial use. (2) An electrolytic method for recovering high grade chromium metal from domestic ores. In seeking more effective means of recovering chromium from the extensive deposits of low-grade chrome ores, particularly in Western States, the Bureau is operating several pilot plants in its laboratories at Boulder City, Nev. Pilot plant tests show that the new benefication method—a roasting and leaching process—is capable of increasing the chrome content of low-grade ore and of raising the ratio of chromium to iron from about 1.7 to 1 to as much as 30 or 40 to 1. Research by the Bureau indicates that it probably will be most economical to produce a residue having a ratio of 5 parts chromium to 1 part iron. When the iron content is lowered, production of standard ferrochromium from the ore thus is facilitated. A third process—known as the sponge chromium process—also was developed by Bureau metallurgists and is being used successfully on a commercial basis for making high-purity chromium from chromite ores. The electrolytic method developed by the Bureau involves the treatment of an aqueous chromium sulfate solution prepared by extracting chromium from chromite minerals as soluble sodium chromate. Electric energy consumed in obtaining high purity chromium metal from ores by this method is less than half that required by the usual electro-deposition process, Bureau metallurgists report.

R. H. O.

New Rubber Reclaiming Process Developed.—(*Chemical and Engineering News*, Vol. 20, No. 12.) A method of reclaiming used rubber which is said to increase the capacity of certain existing

equipment by 60 per cent. has been developed by the United States Rubber Co., Rockefeller Center, New York, N. Y. The processing cycle is reduced from 16 to 9.5 hours and the quality of the finished reclaim is improved because of a change and a reduction in the chemicals used in the process according to W. G. KIRBY, manager of the reclaim development of Naugatuck Chemical Division, which operates the reclaim plant for the company. If used rubber is made available in large quantities, Mr. Kirby said this process along with other developments of this kind may be valuable for increasing present reclaim capacities without construction of additional plant facilities. In reclaiming used rubber, he pointed out, it is necessary to remove or dissolve any fabrics which the used rubber may contain. The scrap is also treated to soften or plasticize the rubber and convert it to a physical state similar to unvulcanized rubber. According to former processes, a digester was charged with scrap rubber, caustic soda, pine tar oils, and water, Mr. Kirby explained, and the mass was heated by steam under pressure and agitated for 16 or more hours. With the new method, air is introduced into the chamber with the scrap, and the steam pressure is increased to raise the temperature; the amount of pine tar oils is reduced, and the mixture is agitated for a much shorter time.

R. H. O.

New High Gas Pressure Cable is Developed in England.—ROBERT J. WISEMAN describes this cable of unusual design and gives test results in *Electric Light and Power*, Vol. 20, No. 7. Known as the "Calender Impregnated Pressure Cable," it has been extensively tested and a 1530 ft. 66 kv. circuit is in actual service as a station tie in the vicinity of London. The development of this new British cable has followed twelve years of study on impregnated paper cable design involving the use of gas at high pressure. Various shapes of conductors were tested as well as different kinds of gases in order to find the most suitable construction. The new cable design is of the solid type made with an impregnating oil having a viscosity comparable to that used in solid type cables. Between the shielding tape over the insulation and the lead sheath, a space is provided to permit the flow of nitrogen gas at 200 lbs. per sq. in. pressure so as to produce a radial compression of the insulation, thereby eliminating formation of voids. The design has not been limited to single conductor only, as three conductor cables have been made both for 66 kv. and 132 kv. operation. In the case of the three-conductor cable, either round or sector shaped conductors may be used; the interstices of the conductors are filled with paper fillers and copper woven cotton fabric tape is used as a binder. Here, as

in the single conductor cable, the lead sheath has an internal diameter 0.100 in. larger than the cable. The London Power Company installed in the spring of 1940 three single-conductor, 66 kv., 0.75 sq. in (955,000 circ. mil) cables, with an 0.235 in. wall of insulation, each 1530 ft. long, to connect the old and new power stations at Battersea. There is a difference in elevation between the two stations of 102 ft. To date these cables are operating satisfactorily. Even with the large difference in elevation, a test for the continuity of gas pressure in the channels, after one year's operation, showed that a change in pressure of only a few pounds per sq. in. resulted in the transfer of gas from one end to the other.

R. H. O.

Wind-Power Plant Operations Going On.—(*Electrical World*, Vol. 118, No. 6.) Operations at the celebrated G. E. S. Morgan Smith-Putnam wind-power generating plant on Grandpa's Knob, near Rutland, Vt., indicate that the unit is generally satisfactory structurally, mechanically and electrically, according to a recent talk before the Providence Engineering Society by PROF. JOHN W. WILBUR of the Massachusetts Institute of Technology, chief engineer of the project. Rated at 1,000 kw., the unit is now in quite constant operation, supplying varying amounts of energy to the Central Vermont Hydroelectric Corp. system, according to wind conditions. An interesting feature of the installation is provision for making motion-picture records (eight frames per minute or eight per second as desired) of instrumental readings in the control house, so that continuous and accurate data may be had upon the performance of the unit and the climatic conditions associated with its use. Preliminary experience points to the probability of obtaining energy from the unit for at least 50 per cent. of the time and full-rated output at about 25 per cent. of the time. At no load the frequency has been governed to within about 0.3 cycle. The large moment of inertia of the two driving blades (tip speed reaches about 200 miles per hour and the weight per blade is about 16,000 lb.) aids governing even under the severe conditions imposed by wind gusts at this mountain top 2,000 ft. above sea level. Thus far 54 miles per hour is the maximum wind velocity at which the unit has been operated and better regulation was obtained than at lower speeds. Dr. Wilbur said that the initial unit was purposely overdesigned, and that an optimum feature capacity for a second unit would probably be of the order of 2,000 kw.

R. H. O.

New Methods for Determination of Molybdenum in Scheelite.—A new method of evaluating certain tungsten deposits on the site of discovery, which will assist in the minerals war production program, has been developed by the Geological Survey, it was announced recently. An improved laboratory method of making accurate chemical determinations of molybdenum in tungsten ores has also been perfected. Both methods are for determining the molybdenum content of scheelite, a common domestic ore of tungsten. In the past the presence of molybdenum in scheelite has been detected only by testing in assay laboratories. One of the methods, which is intended for use in the field, depends on fluorescence; the other, an improved assay method depends on colorimetric chemical analysis. By the fluorescence method the molybdenum content of scheelite can be determined visually in the field by any good observer equipped with the customary ultra-violet lamp. This method is based on the discovery that the fluorescence color of scheelite is directly related to the proportion of molybdenum contained in the crystal lattice of the mineral. In general, concentrates that are not price penalized (excess of 4 per cent.) for molybdenum can be made from any scheelite that fluoresces distinctly blue; those that fluoresce white are borderline cases containing roughly from 0.35 to 1.0 per cent. molybdenum; and scheelite that fluoresces distinctly yellow contains more than 1 per cent. More exact quantitative determination of the molybdenum content of any scheelite containing less than 4 per cent. can quickly be made in the field by comparing the fluorescence color of the powdered mineral with the fluorescence colors of powders of known composition, which are permanently mounted on a card. The improved colorimetric method, permits rapid, precise determination of molybdenum, when it does not exceed two per cent., in specimens of scheelite, or in any molybdenum-bearing ores of concentrates, wherever laboratory facilities and the services of a trained chemist are available. This method eliminates the uncertainties of the usual colorimetric determinations, made with ether extractions, and obviates the need for the standards used heretofore. A stable amber to red molybdenum-thiocyanate color is developed in water-acetone solutions, ammonium citrate being used to eliminate interference by tungsten, and this color is matched by adding standard molybdenum solution to a blank.

R. H. O.

Dry Ice Now Used in .22 Caliber Guns.—L. Y. YONT. (*Refrigerating Engineering*, Vol. 44, No. 2.) If the present plans of Ray J. Monner, president of the Monner Gun Corporation, Denver,

Colo., continue in their successful operations, a cool reception in hot lead from the barrels of the new .22 caliber dry ice guns will greet any Japanese invaders in the Rocky Mountain region, according to the setup of the young inventor with the Home Defense Forces. While the story of carbon dioxide as a refrigerant in the United States is not new and its uses are many in the food field, it is in the later development of the gas as an explosive that the dry ice gun comes into play. The latest models are both safe and economical. The guns shoot approximately 1800 shots on one loading of dry ice at a present cost of about two cents, or a saving of what is equivalent to one fourteenth of the cost of shooting conventional rifles of the same caliber. The gun is charged by simply removing an expanding plug made of synthetic rubber from the fore end of the carbon dioxide container, filling the container with crushed dry ice and replacing the plug. The heat of the surroundings rapidly liquefies the solid ice and it reaches atmospheric temperature. The rifle is then ready to shoot. The valving mechanism releases a small amount of the liquid into a chamber behind the projectile. The subsequent evaporation of the liquid drives the projectile from the barrel. Rough determinations of muzzle velocities show the pressure curve to be much more flat than that of gunpowder. A muzzle velocity of about 1000 ft. per sec. has been reached in firing a 40-grain bullet using a .22 caliber rifle. This performance practically equals that of the conventional .22 caliber ammunition with a mere fraction of the breech pressure. By careful construction and the use of proper sealing gaskets the original difficulties of leakage and efficient valving were overcome. Mr. Monner's applications of the dry ice propellant idea have been confined to the .22 caliber rifles and pistols. He is convinced however, that the same principle is applicable to larger caliber guns for military purposes. Its use in machine guns would, doubtless, allow more ammunition to be carried and prolong the life of the guns.

R. H. O.